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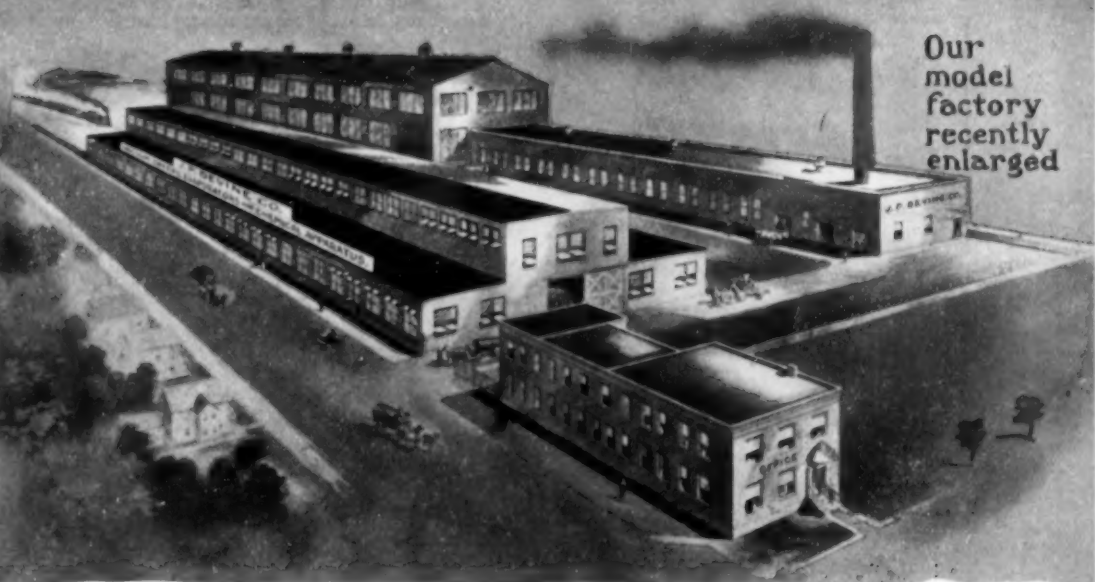
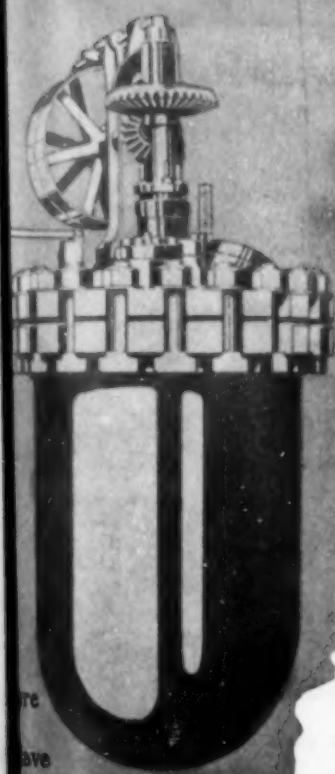
Metallurgical & Chemical Engineering

Volume XIV,

Number 7

April 1, 1916

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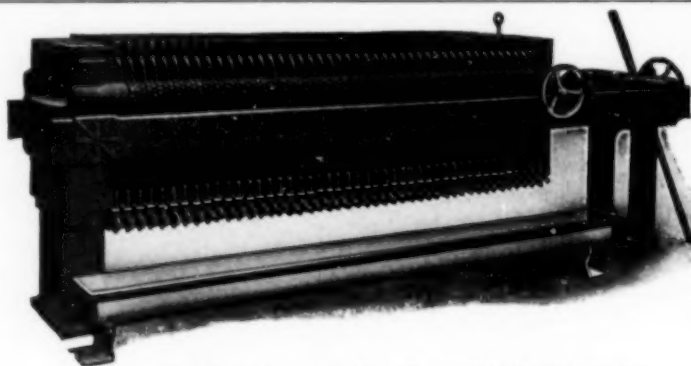
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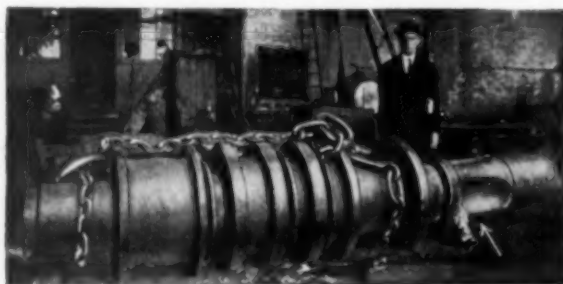
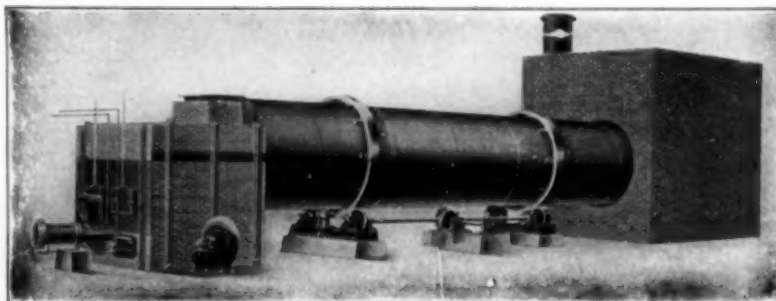
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Metallurgical and Chemical Engineering

A Consolidation of
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The Flotation Process and Our Universities

The flotation process is sweeping the metallurgical world with an elemental dynamic power. Two things will be needed to make its victory complete:—a speedy termination of the litigation on the fundamental patents and the evolution of a universal flotation theory which transfers the flotation process from empiricism into applied science. How long the patent litigation will last no one knows; it seems utterly beyond control. But the evolution of a flotation theory is not, although it is true that so far practice has out-distanced theory by many a mile.

There is a wonderful field for research opened here for our universities. An immense amount of work has already been carried out at some of them. Prof. W. A. Whitaker at the University of Kansas is doing excellent work; so does Dorsey A. Lyon with his associates of the Bureau of Mines in co-operation with the University of Utah, and he deserves highest credit for his efforts to organize the work of the many different investigators in this field into something like a harmonious unit. There are many others equally active. But the main work remains to be done.

One thing is certain. If a universal flotation theory is to be developed, it must be built up from fundamental facts, gradually, step by step, in some such way as sketched in the intensely interesting remarks of Mr. G. D. Van Arsdaile in the flotation discussion at Ottawa last month (see page 325 of our last issue). No purely chemical theory will do nor a physical theory nor an electrical. The elemental force of the flotation process sweeps away the man-made distinctions between different sciences. What is required is a combination of the viewpoints of chemist, physicist, electrician and metallurgist. Indeed, here is a wonderful field for our universities.

Industrial Canada and Niagara Falls

Our esteemed contemporary, *Industrial Canada*, in its March issue prints under the heading, "The Power Famine at Niagara Falls," the three interesting papers by Messrs. Hooker, Landis and Tone (see pages 240, 260 and 261 of our issue of March 1), and introduces them by the following highly suggestive editorial remarks (the italics are ours):

"What is Canada's interest in a further development of electrical energy at Niagara Falls?

"Necessity for bringing about a condition of economic and industrial independence is driving the United States toward the point where further development of Niagara power is becoming absolutely imperative. At two meetings last month of sections of the American Electrochemical Society, one held at Niagara Falls, and the other at New York, addresses were delivered which showed conclusively that from the United States standpoint at any rate, there would have to be considerably more power development at

Niagara Falls, if the work of providing the requisite domestic supply of basic chemical products was to be extended further. As one speaker put it, in any program of industrial preparedness and self-containedness, chemical preparedness and chemical self-containedness play a big part, and its crux is more Niagara power.

"After grasping the import of two or three addresses delivered at these meetings, Canadian manufacturers may well ask what interest the Dominion should take in a question which certainly has an international as well as a national aspect. *If the United States has reached its limit of production under existing conditions, is there not an opening here for an immediate development by Canada of certain electrochemical industries which will provide a part at least of the chemical products now in strong international demand?*"

In the few comments which we will make, we have to perform a duty, both pleasant and unpleasant, in recalling nothing but plain incontestable facts. It is our pleasant duty to pay a compliment to the intelligent way in which Canada has handled its industrial electrochemical problems in the past. This has been characterized by far-sightedness and directness and by a hearty co-operation between government and industry. How the Canadian government has understood its opportunity and responsibility in this matter, has been finely shown by the extended activity over many years of its Department of Mines under Dr. Eugene Haanel, whose work in furthering electric furnace development has become classic. As a British contemporary once put it with perfect truth, this work "stands a monument of legitimate government activity, directed with intelligence and achieving its goal."

It is our unpleasant duty—but a plain duty nevertheless—to recall how industrial electrochemical developments on the Canadian side of Niagara have been helped nicely along by what Canadians may call "good luck"—that is, the power famine on the United States side, increasing steadily in seriousness from year to year. The calcium cyanamid industry was thus expatriated from the United States; what this means to the United States from the viewpoint of national preparedness was fully discussed in our issue of March 1. The Norton Company was forced to go to Canada for the erection of its silicon carbide plant. And there are others. What may be expected to follow might be prophesied with gruesome logical consequence from the present conditions on the United States side of Niagara if not radically changed in short order. We will not prophesy. We will simply state the facts.

The American electrochemical industries at Niagara are of such unique conception and execution, and of such overwhelmingly broad importance for the whole life of this nation, that when the really big achievements of American scientific and industrial genius are mentioned, the Niagara electrochemical industries should be mentioned among the first. They are an achievement the United States has a real right to be proud of. And the fact is that these industries are now almost forced to go begging for the most fundamental needs of their existence—power. And the fact is that in the electrochemical plants on the United States side of Niagara from 125,000 to 150,000 hp. are now used which are being transmitted from the Canadian side of the falls, and that this importation de-

pends on permits revocable by the Canadian government.

We hear so much talk now about national preparedness and national self-containedness. If the above statement of facts will induce a little thinking about this particular phase of preparedness, we need not add a further word.

After Villa, What?

Engineers will hail with unconcealed delight the movement started by the United States which may result in making Mexico a safe place for civilized man to pursue peaceful vocations, as well as prove to both bandit and so-called patriot that our limit of endurance has long since been transgressed. Villa's boast that he would force intervention is not the first sentiment of that kind to be expressed. For several years past American engineers returning from trips into Mexico have brought word of an undercurrent of similar feeling that existed among well-to-do and influential Mexicans, who saw no light of leadership among the squabbling factions. To them the aid of the United States seemed indispensable in restoring peace to their troubled country; and if that aid was not forthcoming in a friendly way and of our own initiative, it would be forced—even by acts of violence on their part.

In the meantime our course of inaction has bred among the rank and file of Mexicans a sense of disrespect for our country and its citizens. We have been forced to abandon legitimate property and the peaceful pursuit of business. Engineers have been wantonly murdered or run out of the country; and those who left took their departure amid the threats and jeers of an irresponsible populace, taunting them with cowardice, ridiculing their government and insulting the flag that was supposed to typify the privilege and right of sanctuary. The cap sheaf of daring and boastful insolence was the invasion of our borderland and the murder of innocent citizens.

These things are past and have forced an action on our part, the final result of which no man can foresee. Our punitive expedition has a definite objective, the capture and subjection of a confessed bandit; but the consequent developments may grow beyond our control and lead to unexpected complications. Our singleness of purpose presumes the sincerity and co-operation of Carranza and the loyalty of his constituents. The quality of the latter is notoriously base, its quantity almost minus. The average untutored Mexican transfers his allegiance with great facility, espousing the cause and supporting the man of the hour. In this lies an element of danger and uncertainty to our expedition, the purpose and magnitude of which may be altered by unforeseen developments. Besides Villa there are other unscrupulous aspirants for Mexican power who might unite with him against an assumed common enemy.

Once begun, however, we hope some definite object may be achieved through our action, both for the good of Mexico and the protection of our own interests. Our long forbearance must disarm suspicion of our good

intentions. If our expressed purpose has to be changed to meet new conditions, let it be followed to a conclusion more final than was achieved at Vera Cruz, so that Mexico may be helped in her distress and made ready for the tremendous development that awaits her and in which American engineers are bound to be a potent factor. And, finally, may no tactical blunder or scandal of unpreparedness or tragedy of "embalmed beef" mar the success of our undertaking.

The Steel Corporation Report

The report of the United States Steel Corporation for the year 1915, just published, is the record of a wonderful year. Its totals, viewed in the abstract, are not remarkable. What was noteworthy in the year was the sweeping change that occurred, from operations at less than 50 per cent of capacity at the beginning of the year, to operations at capacity, in some instances at more than rated capacity, at the close of the year, and from earnings of \$1,687,150 in January to earnings of \$17,722,682 in December. The total earnings of the year, \$130,396,012, after payment of interest on subsidiary company bonds, were less than in six of the thirteen years that preceded, while the tonnage of steel products in the form in which sold, 11,762,639 tons, was less than in two preceding years.

While the 1915 earnings were exceeded in six preceding years, there were larger dividends paid in those six years, to such an extent that in only two of the six was the surplus after dividends larger, those two exceptional years being 1906 and 1907, and in both of them there were large appropriations for new construction, whereby the unappropriated surplus in 1915 was the largest for any year in the corporation's history, the amount being \$44,260,374, and it is interesting to note that the cash on hand increased by 73 per cent as much, to \$94,083,805, or \$26,930,241 more than reported at the close of any previous year.

There is every reason to believe that the cash on hand has been increasing rapidly since the close of the year. The December earnings were sufficient to meet all charges and dividends and leave almost \$10,000,000. The earnings have been increasing since December, and promise to continue increasing for some time to come. While there is much new construction in progress, a part of such expenditures is met by certain charges made against the earnings, while the strictly capital expenditures cannot be running at more than a relatively small fraction of \$10,000,000 a month. Steel prices have been rising up to date, and month by month old and low-priced orders are worked off the books, whereby monthly earnings have been increasing since December and promise to continue increasing. With a stationary market from this date, and full operations, earnings would increase for many months.

Comparing the tonnage output in 1915 with that of 1913, the last year of measurably full operations, there was a decrease of 5 per cent in the tonnage of steel products in the form in which sold. The individual items showed wide variations. There were increases of 66 per cent in billets and sheet bars, etc., and 23 per

cent in wire products, while there were decreases of 41 per cent in rails, 27 per cent in heavy structural shapes, 23 per cent in tubing and pipe, and 27 per cent in finished structural work. These great changes reflect the disturbances caused by the war. The demand for large steel rounds for shells is not reflected in the figures, for the reason that merchant bars, hoops, bands, skelp, etc., are lumped in the presentation, the total showing an increase of 5 per cent.

Considerable interest has been manifested in the effect that might be produced upon the production statistics through the manufacture in 1915 of so large a tonnage of shell steel, involving a heavy cropping from the ingot. Perhaps an influence can be traced, even though the shell steel comprised only a relatively small proportion of the total steel made. The division of the Steel Corporation's tonnage in general was not such as to suggest a larger production of scrap in finishing in 1915 than in 1913, but it is to be observed that in 1913 the proportion of steel for sale to ingot production was 74.3 per cent, and to pig iron produced 87.9 per cent, while for 1915 these proportions dropped to 71.8 per cent and 86.2 per cent respectively, while it is also to be observed that in 1913 the production of pig iron to ingots was 84.6 per cent, while in 1915 it was 83.3 per cent.

Whatever may have been the effect of the war demand in increasing the Steel Corporation's supplies of scrap in 1915, the new construction program looks to a larger employment of pig iron, duplexing being the outstanding feature. A part of the new construction program had not been the subject of public announcement prior to the issuance of the annual report. Of straight open-hearth furnaces there are only ten being built, four at the Lorain works of the National Tube Company, one at the Newburgh works, Cleveland, of the American Steel & Wire Company, and three at the Ohio works and two at the Clairton works of the Carnegie Steel Company. Two complete duplexing plants are being built, one at Gary and one at the South Chicago works, each comprising two 25-ton converters and two 100-ton tilting open-hearth furnaces. At the Donora works, in the Pittsburgh district, two 25-ton converters are being installed, to be completed June 1, to operate in conjunction with the present open-hearth plant, which comprises thirteen stationary furnaces. With the recent completion of the Duluth plant the Steel Corporation's steel ingot capacity was brought close to 20,000,000 tons, and the additions now under way will easily increase the capacity to 22,000,000 tons or more.

The by-product coking construction program is equally impressive. Retorts are being built as follows: Clairton, 200; Youngstown, 210; Central furnaces, Cleveland, 180; Lorain, 225, making a total of 815 retorts. These are in addition to 1262 retorts in the North and 280 in the South, a total of 1542 retorts, so that the number of retorts is being increased by 55 per cent. The coking capacity is being increased much less, of course, since the corporation has 22,153 beehive ovens in the North and 2974 in the South.

Readers' Views and Comments

Waterpower Development

To the Editor of *Metallurgical & Chemical Engineering*

Sir:—There are two great conservation bills before Congress, the passage of which means so much to the economic welfare of the United States that they are entitled, I believe, to your careful consideration and earnest support. These are the bills for enabling and encouraging development of the unused waterpowers in the navigable streams and in the public domain. Because of widespread misinformation and misunderstanding concerning the waterpower business, and because of misapprehension in many minds as to the kind of legislation necessary to bring about waterpower development, there is danger that these bills may be passed in such form as will defeat their main purpose, and actually discourage waterpower development instead of encouraging it.

To secure waterpower development by private enterprise, terms and conditions must be such as will attract investment. With Europe impoverished by war, development must be financed here, and waterpower securities must compete with other forms of investment. Under present laws, for several years past, waterpower development in the United States has been practically at a standstill. A few comparatively small powers have been developed in the West, in the national forests and national parks, in localities where growth of city utilities or need for irrigation, or both, have created a high-priced market, or where conditions have otherwise been exceptionally favorable. No large hydro-electric plants have been built in recent years. Recent reports of the Forest Service show that the average size of power plants built in the national forests under the present revocable permit system is less than 6,000 horsepower, and that permits have been issued for large developments aggregating more than 1,500,000 horsepower, of which none has been built or is being built. I know from personal investigation that efforts to finance these larger plants have failed, and that they cannot be built under present laws.

In ten years past only eight waterpower plants, aggregating less than 140,000 horsepower, have been built upon our navigable streams under the general dam acts of 1906 and 1910. President Wilson, Secretary Lane and committees of both Houses of Congress, after careful study, have announced their belief that new laws are necessary to stimulate waterpower development.

During the last ten years, 1,200,000 horsepower of hydro-electricity has been developed in Europe for use in atmospheric nitrogen establishments. A number of large enterprises of this nature have been planned in recent years, in the South and the West, but they cannot be financed under present laws. The stagnation in waterpower development is not only wasting unnecessarily our fuel supply, but is preventing the establishment of new industries and putting the brakes on national prosperity. One large factory, with \$2,000,000 invested in buildings and machinery especially designed for making water wheels, was shut down for ten months last year, and has exactly one small wheel at present under construction. It is estimated that more than 2,500 engineers in the United States, formerly employed in hydraulic construction, are now out of work.

We are talking of military preparedness, but are wholly dependent upon foreign supplies of saltpeter from which to make nitric acid, an essential in the man-

ufacture of explosives. Our farmers are paying tribute to the Chilean monopoly on every pound of nitrates used in agricultural fertilizers. Capital will not develop the waterpowers necessary to the establishment of electro-chemical industries which would give us military, agricultural and industrial independence, because present laws do not guarantee security of investment or offer hope of reasonable return. It is believed by men who know the practical side of the subject that the Shields bill and the Ferris bill, as amended in the Senate, will offer this needed incentive to investment, and that their passage will be closely followed by extensive development.

The Shields bill received the full endorsement of Lindley M. Garrison, former Secretary of War, whose testimony on the subject before the House Committee on Interstate and Foreign Commerce should be carefully read. An editorial in the *Outlook* of Feb. 9, 1916, states clearly and forcibly the features of legislation necessary to protect public rights. All of these features are included in both the Shields bill and the Ferris bill as amended by the Senate Committee on Public Lands.

Both of these bills retain to the public all title in water rights and power sites, where these are now publicly owned, granting only permits or leases for use for fifty years, at the end of which period the Government may take over all parts of the plants dependent for their usefulness upon these leases or permits, at a fair value to be decided by mutual agreement, or by the Federal courts. No allowance is to be made for any unearned increment or value in any lands or rights granted or leased by the Government or acquired by condemnation under any powers conferred by the acts. During the leasing period, intrastate service and rates are to be subject to State regulation, and interstate service and rates by the Interstate Commerce Commission.

On the ground that use is the highest form of conservation of waterpowers, and to discourage speculation, leases and permits are to be revocable if development is not made within a reasonable time. A moderate rental for public lands used is to be paid by the power companies; also a Federal charge for the benefits derived from Government storage of water. Any attempt to make these powers a source of large Government revenues would naturally add to cost of development and to power prices, which would discourage use, since the lower cost of construction and the greatly increased efficiency of steam plants make their competition with the average waterpower very close.

There is talk of a Water Power Trust. Actually, no such thing exists. It is true that there is a limited number of waterpowers, and that it is not generally possible to have competition between one waterpower and another. Some of our biggest and best waterpowers are located in the mountains of the West, remote from cities. They can be and should be utilized for creating cheap power for irrigation, for electrification of railroad trunk lines, and for great chemical and manufacturing industries to make available the ores and minerals in these waste regions. Present laws, however, are prohibitive of development for such uses. This leaves the corporations operating public utilities in the cities as the largest users of power, and for these reasons the utility corporations naturally control a large percentage, not only of the developed waterpowers, but also of the steam power of the country.

There is nothing abnormal or alarming about this situation, excepting in the fact that so much coal and oil, and so little waterpower, is being used to generate electric current. So far as the control of waterpowers by the utility corporations is concerned, it means simply, and only, that what waterpowers are in use are being used to supply the power market where they are of the greatest value. Power can be transmitted economically for only limited distances, and if waterpowers are to be used at all, they must be used for supplying power within the zone of economical transmission. Where the use of a waterpower will reduce the cost of power and conserve the fuel supply, shall we leave it unused because the most beneficent use can be made by a corporation which, under state and municipal charters with which Congress cannot interfere, controls the distributing system supplying the natural market for power?

Distribution of power, with other public utilities, is considered by most economists to be a natural monopoly—a service that can be better and more economically rendered by monopoly than by competition. President Van Hise, of the University of Wisconsin, in his book on the subject, points out that the generation and distribution of power is a natural monopoly and should be recognized and treated as such. Experience has shown that monopoly in the power business increases diversity of use of current, resulting in increased load factor and consequent reduction of unit cost. Shall we refuse to allow the use of waterpowers to the corporations controlling natural monopolies, and attempt to force unnatural and uneconomic competition in the distribution of power? Shall we, in blind prejudice, compel these corporations, because their business is a natural monopoly, to go on burning coal and oil where they could reduce the cost of their power by using waterpower?

Suppose these power companies were all burning wood, that the government controlled the coal supply, and that to substitute coal for wood under the power-house boilers would cheapen cost of power. Who would be so foolish as to propose that these companies, because they held local franchises giving them control of the natural monopoly of the power business, should not be allowed to burn coal, or that the government should fix the price of coal so high that it would be cheaper for them to go on burning wood and denuding the forests? Still this is the attitude of some men who are trying to scare the country with a Water Power Trust bugaboo, and who are urging that waterpower development should be discouraged by high rentals or taxes on use of water rights and power and dam sites.

There are a few sections where utility corporations having a monopoly of present waterpower development are opposing this legislation because they do not want further development that would lead to the establishment of new industries, increase demand for power, upset the conditions they now enjoy, and possibly bring about reduction in power prices.

Utility corporations and power companies are all subject to state regulation as to their rates and service. The pending bills make companies operating under them subject to Federal regulation where the states do not exercise this power. The cheaper the cost of their power, the lower rates they will naturally be compelled to offer to consumers. Under the proposed legislation, the power companies will not have the opportunity to capitalize or exploit any unearned increment or monopoly value in what is now public property, because they will not be given any title or any rights extending beyond the leasing period, in such property. How, then, can the public be anything but benefited by permitting the power companies to develop maximum power at minimum cost?

By all means, let us have free discussion and criticism of legislation, but let the criticism be based on knowledge and understanding of the facts, and actuated by intelligent wish to make legislation beneficially constructive. Let's get away from personalities and prejudices and consider this whole subject on its merits and demerits.

HERMAN B. WALKER.

Water Power Development Association,
Washington, D. C.

Potash from Kelp in Southern California

BY H. L. GLAZE

At the present time the production of potash in the United States is receiving a great deal of attention from chemists and chemical engineers throughout the country. This is occasioned by the fact that the supply of the German article is cut off by the war in Europe. A number of natural sources of this necessary commodity have been experimented upon, but the one great natural source that seems to be receiving the greatest expenditure of time and money is the kelp of the Pacific Ocean.

There are at least four large interests now at work on the problem and from the immense amount of money being spent it would seem that some one of these must have solved the problem. It is, of course, impossible to learn the details of all the processes being tried, but a glimmering of the trend of the industry as gathered by one in touch with some of the work being done is as follows.

There have been several attempts to utilize the kelp during the last few years, several experimental plants having been built and tried out, but none of them seems to have been a commercial success. Perhaps the first of these was the Pacific Kelp Mulch Company of Terminal Island, Cal., operating a plant for several months, harvesting and cutting the kelp into small pieces, sacking the produce and selling it as a fertilizer. This scheme involved the paying of freight on an immense amount of water as it is a fact that kelp contains about 90 per cent, and little or no effort was made to dry it. The kelp was simply shipped to the farmers, who spread it upon the land and plowed it under.

Another company was formed to exploit kelp on a more scientific basis, about four years ago. This concern, which was financed by popular stock subscriptions, built an extensive plant at Cardiff by the Sea, Cal. They probably never produced any potash on a commercial scale and their efforts ended when their creditors took over their assets. This ill-fated venture was followed by the American Potash Company of Long Beach, Cal., which fell heir partially at least to the process and machinery of the Cardiff plant, and to the best of the writer's recollection some of the same men were connected with both concerns.

The plant of the American Potash Company consisted of a kelp harvester, storage bins, a drier, calcining furnaces and leaching tanks. The scheme of operations was approximately as follows: The kelp was harvested and cut into pieces about 6 in. long on the harvesting barge, it was then towed ashore on the barge and landed on the dock by means of a derrick and hay fork. The main storage consisted of bins, although a good deal of the material was piled on the ground, which seems to indicate that the capacity of the harvester exceeded that of the rest of the plant. From the storage bins the kelp was conveyed on a belt to the feeder of the drier which was of the rotary direct-heat type burning crude oil. Here the moisture content was brought down to about 10 per cent, and some was sold in this state as fertilizer and the remainder was burned

in reverberatory furnaces. The ash from these furnaces, which also burned oil, was leached with water and the soluble salts consisting largely of KCl and NaCl were separated out by fractional crystallization. This plant did not seem to be successful at the prices then obtainable for potash salts, although the promoters claimed that the capital available was not great enough to enlarge the plant to an economical size.

The foregoing attempt was followed by a plant in San Diego, Cal. This factory also used a drier of the direct-heat type and some other machinery. The proprietors are reputed to have taken out patents on a "deglutinizing" agent which they mixed with the cut kelp, afterward grinding the mixture to a pulp and filtering off the liquid portion which was supposed to contain the potash. This liquid was evaporated to obtain the salts and the solid portions were dried and used as a fertilizer. These people also claimed to have discovered that if the whole kelp were fed into a drier and heated to such a point that it was partially burned or "seared" over, it would be converted into a much more valuable fertilizing product than if it were merely reduced to dryness. In spite of all this the process did not prove a success and the plant was finally leased by one of the present concerns as will be mentioned later.

Since the war started, the price of potash having gone up, two or three attempts were made to revive the old plants and also to dry kelp by the heat of the sun. The latter did not work out as the operation was necessarily carried on at tide water and the heavy fogs at night wet the kelp about as much as it was dried out in the day time. This brings us down to the present time and to a consideration of the great forces now at work on this source of potash.

About the first in the field during the recent revival was the American Products Company which started to do experimental work at Pasadena, Cal., and which later bought the effects of the American Potash Company and moved to the property of the latter at Long Beach. This company is being financed by Mr. George Simmons of the Simmons Hardware Company of St. Louis, Mo. Mr. Isaac Nailor is the chemist and originator of the process which the company is using. Considerable mystery surrounds the operations of this concern, but it was learned from Mr. Nailor that the principal product of his process would be a cellulose insulating compound for pliers and knife handles for soldiers' use in the field. He also mentioned that the cellulose that he could produce could be nitrated and used for explosives. The American Products Company has to date spent a great deal of money without seeming to have accomplished much. They built at an expense of about \$10,000 a harvesting barge that exceeded in size anything before attempted here. This barge had sickle blades like a mowing machine which would cut a swath 40 ft. wide and the depth of cut on the kelp was 6 ft. The kelp was to be elevated to two large macerating machines which were to reduce it to a pulp and in this condition it was to be conveyed to barges to be towed to the plant on shore. The machinery was to be driven with gasoline engines and an original system of propulsion and steering of the cutting barge was attempted. This harvesting machine was more or less of a failure and the report is now current that it has been dismantled and a new barge is being built along different lines.

The barges for carrying the kelp ashore were to have valves in the bottom and the plant was to have a marine railway to haul the barges out of the water at each trip. The macerated kelp was to be sluiced out of the barges by way of the valves in the bottom by the use of waste liquors from the reduction plant. These details are

about all that is publicly known of the Nailor process except that immense driers, evaporators, crystallizers and boilers are projected and the plant is being laid out to handle hundreds of tons per day of the raw material. Various patents have been applied for on the details of the process.

The significant thing about this project is that the potash will be a by-product of the manufacture of cellulose products. Incidentally it is understood that this process contemplates the heating of large bodies of material to a high temperature and under pressure in retorts. This company has done considerable work on a small scale and they seem to have satisfied themselves that they will be able to achieve their aim.

The second large experimenter to appear in the field was Swift & Company, the meat packers, who evidently need potash for their fertilizer products. Messrs. S. G. Smith and G. H. McCoy are the engineers in charge of the Swift kelp plant and Mr. Smith has been on the ground for several months collecting data and doing experimental work preparatory to the building of a plant. Swift & Company leased the small plant at San Diego mentioned above and have thoroughly satisfied themselves by a test of several months that they could make a satisfactory fertilizer material from kelp. This experimental plant or at least that portion of it used in the experiments consists of a wharf for landing the kelp from the cutting barge, a conveyor and a drier of the direct-heat type 54 in. in diameter and 35 ft. long. Swift & Company afterward added another drier unit 60 in. in diameter and 40 ft. long, the kelp being fed into the cold end of the first and larger drier and discharged into a conveyor carrying it to the hot end of the second and smaller drier from the cold end of which it was discharged with a moisture content of about 10 per cent. Crude oil was used as fuel and the drying was carried on without carbonizing the product to any great extent. The product was then ground in a swing hammer mill, sacked and shipped to the fertilizer factory in the east.

The product from this plant contains the whole body of the kelp, the potash, amounting to about 15 per cent by weight, and about 10 per cent water. A slight amount of nitrogen is also claimed. This material is used to make up the potash requirement of the fertilizer and the cellulose and other inert constituents are figured as filler the same as tankage. At the present price of potash it will be seen that this dried kelp is a very valuable article and even if it did not run over 10 per cent potash, it would stand shipping to the company's Eastern fertilizer plants. Swift & Company evidently found it to be a profitable venture, as they are now building a larger plant at San Diego, Cal.

This new plant will contain ten direct-heat driers 60 in. in diameter by 40 ft. long, burning crude oil, and probably working in series the same as those in the experimental plant. The plant is being housed in steel and corrugated iron buildings. It will be electrically driven by alternating-current motors with one motor to each pair of driers. The dried kelp will be ground before shipment East. It is estimated that this plant will have a capacity in excess of 200 tons of wet kelp per twenty-four hours, giving about twenty tons per day of dried material containing from 10 to 15 per cent KCl. This company also designed and built their own kelp-harvesting machine which works on the ordinary mower principle. They have purchased two scows and a tug for use in the work of gathering the kelp. Their factory will be located in the center of the water front of the city of San Diego on the Santa Fé Railroad and will be arranged to handle the output on an efficient basis. It is said that this plant will be permanent, if

it shows any success at all, even though after the war the price of foreign potash be reduced.

The Diamond Match Company is also in the field with a small plant at Long Beach, Cal. Very little is known of the intentions of this company except that they evidently need potash in their match factories and that they have been experimenting to some extent in the north. Mr. O. Z. Howard is the engineer in charge of the work. They have let contracts for several wooden buildings and it is known that they have bought three direct-heat driers in the East. It is rumored that the process to be used in this plant includes a freezing operation, but it is not known whether the potash will be the principal product or a by-product of the process.

The crowning achievement along the kelp potash lines will be the venture of the Hercules Powder Company at San Diego. This plant will be an immense structure with many buildings, acres of tanks and many tons of especially designed machinery and chemical apparatus. The construction work is in the hands of Charles C. Moore & Company of San Francisco, who have upward of 500 men working. Practically nothing is known of the Hercules process, but it must be to some extent similar to the Nailor process. If the reports may be believed this plant will turn out large quantities of nitro-cellulose from kelp and hundreds of tons of potash as a by-product. None of the details of the projected process is yet apparent, but it is known that several large driers have been purchased in the East and some of the buildings on paper look very much like nitrating houses. The writer has seen some of the drawings of this plant and as everything seems to be of the very best material and construction it must be that the engineers of the Hercules Powder Company have done lots of preliminary work in order to warrant such expenditure.

It would seem impossible that all of these new processes would prove failures. Therefore we may expect to see some new and more or less revolutionary or at least unexpected things occur in the cellulose and fertilizer industries in the next few months. Cellulose good enough for nitrating means practically pure cellulose and that means cellulose suitable for many purposes such as viscose, viscid, photographic films, celluloid, artificial silk, paper, etc.

The kelp beds of the Pacific have been investigated by the Department of Agriculture and one or two bulletins have been published. Very complete maps have been made of the various beds extending from Alaska to Mexico and there has been some talk of Federal regulation of the use of these beds.

There is an amazing diversity in the various statements published regarding the amount of potash, iodine and other constituents of the kelp and the writer has seen the weight of the wet kelp put all the way from fifteen to forty-five pounds per cubic foot. The moisture content is an equally variable quantity and to the best of my knowledge no data have been published as to the amount of cellulose contained, nor anything as to the nature of the glutinous part of the plant and its possible use. There seems to be here a very fertile field for research work and it will be interesting to observe the progress of the future work on this material.

Los Angeles, Cal.

The annual meeting of the American Electrochemical Society will be held in Washington, D. C., from Thursday to Saturday, April 27 to 29, 1916. Those members and guests who will go to the meeting from New York and like to travel in the special car or cars to be provided for that purpose on a Wednesday afternoon Pennsylvania Railroad train are requested to notify the secretary of the New York section, Mr. J. M. Muir, 239 West Thirty-ninth Street, New York.

The Glass Industry

Meeting of New York Section of Society of Chemical Industry

A symposium on the American glassware industry was held at a meeting of the New York Section of the Society of Chemical Industry at the Chemists' Club March 24. Preceding the presentation of the papers the annual election of officers for the coming year was held. The following officers were elected: JEROME ALEXANDER, chairman; PARKER C. McILHINEY, secretary. The new chairman presided at the meeting.

The first paper was on the "Development of Low-Expansion Glasses," by Dr. E. C. SULLIVAN, chief chemist of the Corning Glass Works, Corning, N. Y. Dr. Sullivan gave a very interesting description of the methods of testing glass and the strict specifications which must be met for certain purposes such as laboratory ware.

The chief difficulty that the manufacturer encounters in developing low-expansion glass is that as expansion of the glass decreases the fluidity also decreases. Boric oxide counteracts this tendency to some extent, but above a certain percentage it affects the stability. The method of testing the expansion of a piece of glass which is used by Dr. Sullivan is a method developed by Holborn and Day, using a water-jacketed electric furnace, with two totally reflecting prisms sighted on the ends of a piece of glass. The piece is heated to 350 to 400 deg. C, and the method is accurate to a few tenths of 1 per cent. Other tests described were those of placing a number of glass canes side by side in a vertical electric furnace and at the proper time dropping them through the sliding bottom of the furnace down into water. The tensile strength and modulus of elasticity are determined by the ordinary methods. The tendency to crystallize is determined by a method developed in Jena. The resistance to attack by reagents is determined by making beakers of the glass and heating them filled with distilled water or with the reagent in question at about 80 deg. for considerable time. The water is then tested for dissolved substances.

Dr. Sullivan then mentioned a glass which his company has developed having a very low coefficient of expansion (0.0000032), and which has consequently a great resistance to sudden changes of temperature. It is also very little soluble in water, acids or alkalies, and compares favorably with the best European resistance glass. Samples of the glass were shown. Some very interesting lantern slides of various tests made on this glass and of its application to baking dishes were shown. It was pointed out that radiation in baking dishes was really the paramount factor rather than conduction. Slides were shown of comparative tests made on baking in metal and glass dishes, which proved conclusively that the glass dishes attained a higher temperature in the same time than the metal dishes and were consequently more economical.

In reply to questions, Dr. Sullivan said they had encountered serious delays in making laboratory ware, but were now in a better position; he said that they had not taken up the manufacture of glass for vacuum apparatus and that he did not think they could compete with Europe on a duty-free basis, and as institutions obtain glassware duty-free it was suggested that something ought to be done to protect the American manufacturer.

The next paper was presented by Mr. S. R. SCHOLLES of the Mellon Institute, Pittsburgh, and chemist of the H. C. Fry Glass Co., Rochester, Pa. Mr. Scholles said the art of glass-making had far outrun the science and there were many things that needed a scientific expla-

nation. He reviewed the history and development of glass-making in this country and then took up the manufacture of cut glass and tumblers. He gave a very interesting description with numerous lantern slides, showing the making of the pots, the furnaces and the melting process. The operations of gathering and pressing, selecting ware, cutting and polishing, blowing, pulling stems and foot-setting, and finishing blown ware, were described in considerable detail. Specimens of ware in the various stages of manufacture were shown.

Mr. Scholes then took up the chemistry involved in glass-making, especially the problem of decolorizing. The use of manganese was explained and a new theory advanced for its behavior in glass. The burning out was thought to be due to the formation of manganites or manganates; that is, to a chemical change rather than a physical one. Some substitutes suggested for manganese were nickel and selenium. Nickel has possibilities, but selenium offers great difficulties, and Mr. Scholes thought it unlikely that it would ever find much use as a decolorizer. He said the development of a perfect decolorizer was one of the greatest needs of the present-day glass making.

This paper brought out some very interesting discussion as to the theory of decolorization. It was pointed out that microscopical examination might yield some information as to the physical structure and that the change may be a physical rather than a chemical one as in the case of gold ruby glass. Another suggestion was made that the same ingredients as in the glass might be placed in aqueous solution and tested in that manner. The application of X-rays to coloring glass was discussed and a recently patented process was stated to make it possible to produce a color in decolorized glass to any desired depth under the surface or completely through glass 1 in. thick.

The last paper was presented by C. OSGOOD ANDREWS, special representative of the Plate Glass Manufacturers of America. Mr. Andrews first reviewed the history and development of glass-making and then gave a very interesting description of the manufacture of "glass we see through." The methods of making plate and window glass were described and general conditions governing the glass industry were cited. The paper was especially interesting in that it discussed the present status of the glass industry and pointed out that we were not obtaining any glass from abroad at the present time. American made glass was compared with foreign glass.

The meeting was well attended and a lively interest was shown in the glass industry. Adjournment was made at a late hour.

Meeting of New York Section of American Institute of Mining Engineers

A very interesting meeting of the New York Section of the American Institute of Mining Engineers was held at the Machinery Club on the evening of March 23. The meeting was preceded by a dinner, and was very well attended. Mr. Frank J. Sprague, member of the Naval Consulting Board, who was to talk on some phase of the naval problem, was unfortunately unable to be present, and in his place Past-President W. L. Saunders, also a member of the Naval Consulting Board, gave a very interesting talk in his genial manner on the work of the board, with especial reference to the sub-committee on organization. This was followed by an illustrated talk by Dr. Charles L. Reese of the Du Pont Powder Company on explosives. Dr. Reese's

address was very interesting and instructive, and the meeting was thoroughly enjoyed by all those who attended.

Spring Meeting of American Chemical Society

The fifty-second meeting of the American Chemical Society will be held at the University of Illinois, Urbana-Champaign, from Tuesday, April 18, to Friday, April 21, inclusive. General meetings will be held in the university auditorium, and meetings of divisions will be held in the Chemistry Building. In conjunction with the meeting the splendid new chemistry building of the University will be dedicated, and an exhibition of chemical products and apparatus will be held in the large first floor laboratories of the new building. The local section of the society invited the leading manufacturers of chemical products and apparatus to participate in this exhibition. A partial list of exhibitors is given further on.

The chairmen of the different local committees are Professors Edward Bartow, W. A. Noyes, C. W. Balke, C. G. Derick, D. M. McFarland, E. W. Washburn, S. W. Parr, G. D. Beal, H. L. Olin and Miss Isabel Bevier.

The following provisional program will give an idea of the plans for the Urbana meeting. The session Tuesday morning will be given up to presentation of some four important papers of general interest. Dr. G. H. A. Clowes, of the Gratwick Research Laboratory, has agreed to present for the first time the results of his extended research "On the Influence Exerted by Electrolytes on the Equilibrium of Emulsions, Jellies and Living Cells" (with demonstration). Three other papers will be announced in final program. Tuesday afternoon will be a general "get-together" excursion to parts of the university grounds. The points of interest to be seen are the model dairy, the annual spring floral display and floricultural greenhouses, the vegetable greenhouses, model dairy barns, and prize cattle exhibit in the new stock-judging pavilion. After a concert by the University of Illinois military band, a "get-acquainted" smoker will be held Tuesday evening.

On Wednesday morning there will be division sessions, while in the afternoon the dedication of the new chemistry building of the university will take place. Governor Edward J. Dunne of Illinois will preside, and addresses will be made by President Edmund J. James, Dr. W. R. Whitney and Dr. Alexander Smith. In the evening a banquet will be held at Masonic Temple.

On Thursday division meetings will be held and in the afternoon there will be excursions on the University campus. The points of interest will include the laboratories of mechanical, mining, hydraulic, electrical, railway, and ceramic engineering, the vivarium, the botany annex, and the activated sludge plant. On the evening of Thursday there will be two illustrated lectures, by Dr. Charles L. Parsons on the production of radium, and by Dr. Curtis F. Burnham on the use of radium in the treatment of cancer.

On invitation of the Commercial Club and manufacturers in Danville the society will go to Danville on Friday for the purpose of visiting the Hegeler Brothers' zinc smelter and sulphuric acid plant, the Western Brick Company's kilns, and the Three Rivers Coal Company's strip coal mine.

Special attention is called to this extension. The smelter of the Hegeler Zinc Company was built in 1908 and is one of the most modern and best arranged in the country. The capacity has recently been trebled. The smelter utilizes the fumes from roasting the zinc

ore. The brick and tile plant of the Western Brick Company is one of the largest in the country, and of especial interest are the open pit shale and coal mines furnishing material and fuel. The strip pit coal mine gives a splendid illustration of the location of coal. Usually a bed of coal a quarter to a half mile long and 50 to 100 ft. wide is exposed. Arrangements are being made for optional visits to other plants if the members desire.

The list of exhibitors registered prior to March 8, 1916, for the exposition of Chemical Products and Apparatus, to be held in connection with the convention, is as follows: Abbe Engineering Co., P. Blakiston's Son & Co., Celluloid Zapon Co., Central Scientific Co., Dearborn Chemical Co., Duriron Castings Co., Eimer & Amend, Elyria Enameled Products Co., Fairview Fluorspar Co., General Electric Co., Henry Holt & Co., International Instrument Co., Jeffrey Dewitt Co., Kimble-Durand Glass Co., Laboratory Supply Co., Leeds & Northrup, Lenz & Naumann, Libbey Glass Co., Longmans, Green & Co., Emil E. Lungwitz, Macbeth Evans Glass Co., Manhattan Rubber Co., McGraw-Hill Book Co., McIntosh Stereopticon Co., Metallurgical and Chemical Engineering, Mojonier Bros. Co., National Carbon Co., National Lead Co., Norton Co., Pfaudler Co., Schaeffer & Budenberg Mfg. Co., Schutte & Koerting Co., Scientific Materials Co., Sowers Mfg. Co., E. R. Squibb & Sons, Standard Calorimeter Co., Sweetland Filter Press Co., Thermal Syndicate Co., Thwing Instrument Co., Toch Bros., U. S. Bottlers Machinery Co., John Wiley & Sons.

Dr. Charles L. Parsons (Box 505, Washington, D. C.) is the secretary of the American Chemical Society.

The Western Metallurgical and Chemical Field

Alkali Deposits of California and Oregon

At the present time there are but few practical data obtainable relative to the great deposits of natural alkali situated in California and Oregon; but believing that some of the Western alkali lakes are likely to assume commercial importance, we are glad to present herewith some notes on the subject by Mr. THOMAS M. SKINNER, JR. In his opinion Owens Lake, Cal., and Summers, Abert and Alkali Lakes, Ore., offer the best opportunities for recovery of dissolved alkali salts. Fol-

	Owens Lake, Cal.	Summers Lake, Ore.
NaCl	59.51%	27.10%
Na ₂ CO ₃	41.34	43.91
NaHCO ₃	4.41	21.41
K ₂ CO ₃	2.21	3.63
Na ₂ SO ₄	12.06	2.21
SiO ₂	0.095	0.87
Fe ₂ O ₃ and Al ₂ O ₃	0.062	....
Total	99.687%	99.13%



OWENS LAKE, CALIFORNIA, LOOKING TOWARD SALINE VALLEY AND WHITE MOUNTAINS

lowing is an analysis of the solids contained in the waters of Owens and Summers Lakes:

The past year is the first time that practical steps have been taken on a large scale to effect a separation of potash from these waters. This was successfully done at Owens Lake, making a high-grade fertilizer salt from the spent waters obtained from the manufacture of soda ash. These spent waters, which were formerly wasted, contained 4.25 per cent potash which is now recovered as a valuable by-product.

Owens Lake is situated south of Mt. Whitney and northwest of Death Valley, Cal., being between one of the highest points above, and the lowest point below, sea-level in the United States. The lake is reached by the Southern Pacific railroad from either Los Angeles, Cal., or Reno, Nev. The Southern Sierra Power Co. has distributed electric power around three sides of the lake, and furnishes power at about 1½ cents per kilowatt-hour and light at 10 cents. The lake is 27 miles long and 23 miles wide, and is estimated to contain 4,000,000 tons of sodium carbonate alone, with proportionate amounts of the other salts shown in the analysis.

At Summers Lake, Ore., the water excels that of Owens Lake in some respects, but generally speaking is about the same. Abert Lake water is quite like that of Summers. Both are within 30 miles of Pleasant View, Ore., where the railroad connects with Reno, Nev. Alkali Lake has produced great quantities of crude sodium carbonate, but the distance from the railroad does not yet warrant the manufacture of products.

The most important alkali products constantly in demand on the Pacific coast which can be made from these waters are: Caustic soda, dense soda ash, light soda ash, bicarbonate of soda, silicate of soda, potash, sal soda (snowflake and monocrystal), table salt, and others.

About 5000 tons per year of dense soda ash is being produced at Owens Lake at a cost of \$6.15 per ton. At the present time the selling price is about \$21 per ton. This product is made partly by methods of recrystallization and partly by the direct furnacing of crude sodium carbonate, the latter being obtained by solar evaporation and fractional crystallization. Recrystallized dense soda ash costs about \$3 per ton more for manufacture than the other product, but is far superior to it for glass and paper manufacture. Considerable quantities of this high-grade material are used on the Pacific coast; and with the exception of the product from Owens Lake the entire supply is shipped to the coast from, or east of, Hutchinson, Kans. The Solvay company is the chief source of supply, making soda ash from sodium chloride by the Solvay process.

Caustic soda is a product now in great demand, bringing over \$100 per ton. It should be produced at Owens Lake for about \$21 per ton. Liquid caustic could be



POTASH AND SODA ASH VATS AT OWENS LAKE, CALIFORNIA. KEELER, CAL., IN DISTANCE

marketed in large quantities on the Pacific coast, if produced as near the market as either Owens or Summers lakes, since this form is preferred by such consumers as oil refiners, sugar manufacturers, meat packers, tanners, wool scourers, and in the dried fruit industry. Seven thousand tons of caustic soda is sold yearly in San Francisco alone.

Bicarbonate of soda can be made at about \$2.75 per ton, and at present prices will bring from \$12 to \$14. This article contains about 12 per cent moisture, but upon drying or heating to light soda ash it would bring about the same price as dense ash. Several Western concerns are now making a desirable product in the form of a washing soda by compounding light ash, bicarbonate of soda and borax.

Remarkable Tungsten Market

During the past year and a half we have become accustomed to spectacular prices for metals, but we believe that the case of tungsten surpasses anything relating to the common metals. There have been some unusual advances in price for certain chemicals, but among the ordinary metals in commercial demand tungsten holds the record for rapid and extreme increase in price. About the beginning of the war, and in fact for the year 1914, the price of tungsten averaged about \$6 per unit of 20 lb., basis of 60 per cent WO₃. For the week ending March 18, 1916, the price for 60 per cent concentrate was published at \$90 per unit; and owing to the competition between buyers and the active bidding for good material, \$100 and more was paid for the grade mentioned.

In Boulder County, Col., the greatest activity prevails. Mills are buying ore that in former times would not be worth mining, and are paying such prices for it that small producers are reaping phenomenal profits. Ore containing 3 per cent tungstic acid will bring \$16 per unit, or \$48 per ton; 7 per cent ore will bring \$40 per unit, or \$280 per ton, and so on up to \$90 per unit, or \$5400 per ton for 60 per cent concentrate. With ore at such prices and with a ready market at hand, there has been some difficulty in preventing theft of rich ore or concentrate, and the scene of "high-grading" in Colorado has been shifted temporarily from Cripple Creek to Boulder County. The future of the industry is highly speculative and uncertain. Opinion differs as to the effect on tungsten prices when the war ends. Some incline to the belief that the bottom will drop out of the market suddenly and that it will be difficult if not impossible to market the metal. Others think that while the price certainly will drop, it will still remain at a figure in excess of normal prices for preceding years.

Company Reports

During the year 1915 the Yukon Gold Co. acquired additional properties in California and Alaska, the estimated gross gold content being \$3,800,000 and the estimated net profit \$1,500,000. The seven Dawson dredges were operated for 88.1 per cent of the season of 147 days, mining 5,041,075 cu. yd. and producing \$2,456,597, or an average of 48.73 cents per cubic yard. The average cost, including depreciation, was 26.46 cents per cubic yard, which is less than the cost for 1914 by 1.16 cents. There was a reduction in value of the ground dredged amounting to 5.48 cents per cubic yard. During the season a total of 380,340 sq. yd., or 64.7 per cent of the ground handled, had to be thawed by steam. In the Iditarod the season was 196 days, and the dredge handled 926,956 cu. yd., producing gold to the value of \$845,998, an average of 91.3 cents per cubic yard. The average cost was 38.7 cents, which was lower by 11.5 cents than for 1914. Due to better dredging conditions and to the installation of sand elevators, this

dredge handled 4717 cu. yd. per day, a gain of 1216 yd. over the preceding season. The three California dredges handled 3,818,126 cu. yd. of gravel, yielding \$437,852. The average cost was 4.51 cents per cubic yard. By hydraulic operations the yardage mined amounted to 3,031,647 cu. yd., producing \$412,535 at a cost of \$243,247. The working cost was 7 cents per cubic yard. The water duty was 6.13 cu. yd. per miner's inch. The total profit for the year was \$2,121,031; deductions, \$1,036,081.

The Mary Murphy Gold Mining Co., Colorado, operated its milling plant throughout the year 1915 on a basis of 175 tons per day. The introduction of the flotation process is credited with a large part of the profit for the year. The cost of mining for the year, on the basis of 60,561 tons, was \$3.20 per ton as against \$3.08 for 1914 when 53,211 tons was mined. Milling cost per ton for 1915 was \$1.99; for 1914, \$1.96. The distributed milling cost for two years is as follows:

	Per Ton	
	1914	1915
Crushing mill, operating	\$0.30	\$0.26
53,012 tons 1914		
57,310 tons 1915		
Crushing mill, maintenance	0.07	0.07
Concentrating mill, operating	1.04	0.76
48,526 tons 1914		
55,880 tons 1915		
Concentrating mill, maintenance	0.20	0.20
Ore tests and experiments		0.01
Flotation work		0.13
Mill water supply		0.02
Tailing dams		0.12
Electrostatic mill, operating	4.90	3.08
(zinc middling only) 4060 tons 1914		
6013 tons 1915		
Electrostatic mill, maintenance	0.36	0.66
Electrostatic mill, royalty	0.75	0.75

The operating profit for the year, after providing for depreciation was \$220,415, due in great measure to the high price of zinc. About one-half the net profit, or \$110,000, has been set aside as a fund for acquiring new property.

Department Metallurgical Research Exhibit at San Francisco Exposition Now on Display at University of Utah

The exhibit of charts and cases of minerals displayed by the Metallurgical Research Department of the University of Utah at the Panama-Pacific International Exposition has arrived at the University and is being set up in the mining and metallurgy building. The exhibit consists of two large plate glass cases containing an educational series of Utah mineral and metallurgical specimens representing the consecutive steps in typical ore dressing and metallurgical processes, along with fifteen charts descriptive of the mining and metallurgical resources of the State of Utah.

Although available space is difficult to find in the crowded building, portions of the exhibit are being set up wherever any suitable space can be spared. This display material is directly in line with the work of the mining, metallurgy and metallurgical research departments, and will serve as a nucleus for a more comprehensive series of specimens and charts to illustrate the types of minerals and ores and the commercial products possible to obtain from the same that make up the very extensive mineral resources of the State.

It is the desire of those in charge of the departments to build up a mining and metallurgical museum somewhat after the nature of the exhibit by the U. S. Geological Survey that was on display in the Palace of Mines and Metallurgy at the San Francisco Exposition, entitled "Minerals and Their Uses." In the proposed collection will be shown the principal minerals and ores of Utah along with the product resulting from the commercial treatment of the same, together with the uses to which these minerals and products are applied.

The series will make an attractive and highly educational display and will serve to stimulate the ambitious student and interested visitor to lend his efforts toward developing the mineral resources of the State of Utah.

The Iron and Steel Market

The iron and steel market has grown less clearly defined. As to steel, it is largely sold to a standstill, while in pig iron everything hangs upon the question whether the large steel interests will be forced into the market to eke out their own supplies, which in most quarters are thought to be running short.

There have been two distinct developments in the past fortnight, distinct in themselves, but certainly furnishing no distinct indication of what the steel market is to do next. The first is that many buyers have lost interest in contracts for far forward delivery. They regard the prices so high that there would be a great risk in buying for the very late deliveries the mills would offer, and they find themselves unable to make a fair estimate of what their condition will be when such delivery period would arrive. It seems somewhat curious, after all, that such a feeling did not develop sooner. The condition of the market has changed in this respect, that whereas for months there were buyers ready to contract for much more steel for late delivery than the mills were willing to obligate themselves upon, it would now be difficult for the mills to sell large tonnages on open contracts, say, for the first half of 1917. It must be understood, of course, that the mills have been making no such effort. For months they have simply been picking out, of the business offered, such as they cared to accept.

Another new feature in the market is that some of the sellers of steel are unwilling to commit themselves that this price or that price is their minimum quotation. It does not appear that they have weakened in price, but rather that they quote higher and higher prices week by week but in the spirit that they do not wish to be placed on record that these higher prices are the minimum they would accept. The only explanation at all acceptable for the taking of this position is that the mills wish to curtail as far as they can the embarrassment that faces them whenever the time comes that they will have occasion to solicit business again. If they are not committed now to definite prices, then when they quote a certain price later there will be less occasion for the customer to regard the price as a cut from an established basis. While there is no doubt that present prices are so high as to make it impossible for some buyers to take hold, it does not appear that the mills are modifying prices according to the ability of consumers to pay. It rather seems that there is a growing feeling towards "preparedness" for the inevitable reaction. The mills are by no means a unit on anything, however. Some have "called in their salesmen" long ago, because they did not want business. Others, perhaps the more enterprising, have instructed their salesmen to make their usual rounds with the greatest fidelity, though they do not want orders, the idea being that the reappearance of a salesman, after a long absence, would naturally be construed as evidence that the market had weakened.

The pressure for steel has increased further, and this is indicated by higher prices being bid for prompt shipment. The large mills realize that their prices have advanced far beyond levels they could expect to maintain indefinitely and are, therefore, interested in obtaining such prices as can be secured. If they book less forward business, they stand to be able to work up to the point of making earlier deliveries, and thus, in

a sense, obtaining premium prices for prompt shipment if the markets hold strong long enough. As to the great bulk of their tonnage, the steel mills are sold up through the year, but it is probable that earlier deliveries can be arranged with certain buyers, upon occasion, than is generally admitted.

Pig Iron

The market as a whole has been less active the past fortnight than in the early part of March, but the undertone appears very strong indeed. The merchant furnaces are very well sold up and there is no indication that production can be materially increased. Meanwhile stocks of pig iron are diminishing and the steel works are increasing their capacity. It is thought in many quarters they will be forced into the market shortly, and the general view is that if such is really the case the pig iron market will advance very sharply. There is ample room for an advance, of course, since finished and unfinished steel have advanced on this movement about \$25 a ton, while pig iron has advanced only \$5 to \$6. Rebecca furnace at Kittanning, Pa., under lease to the Jones & Laughlin Steel Company since last October for the manufacture of ferromanganese, is to pass to the control of the owners at the expiration of the lease. The stack will be blown out for relining about May 1, to be blown in again about July 1 on basic iron. A deal has been effected for 100,000 tons of iron ore, 5000 tons of basic iron a month for ten months being furnished the seller of the ore. We quote: No. 2 foundry, delivered Philadelphia, \$19.75 to \$20.25; f.o.b. furnace, Buffalo, \$19 to \$19.50; delivered Cleveland, \$19; f.o.b. furnace, Chicago, \$19 to \$19.50; f.o.b. Birmingham, \$15 to \$15.50; f.o.b. valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, \$21 to \$21.50; basic, foundry and malleable, \$18.50 to \$19; gray forge, \$18 to \$18.50. Ferromanganese on contract is held at \$175, delivery being far in the future, chiefly 1917, while prompt lots have brought up to \$400 in a very excited and irregular market.

Steel

The market for unfinished steel continues very narrow so far as transactions go, there being only odd lots developing from time to time. It is thought a large tonnage of billets could be sold if desirable deliveries could be offered. We quote, practically nominal, \$45 for Bessemer or open-hearth billets or sheet bars. Rods are about \$60, but are difficult to secure at any price.

Finished Steel

It appears that there was some talk of putting up the price of rails, which have not changed, as to Bessemer, since February, 1901, but sales of over half a million tons have been made for 1917 delivery, setting at rest the rumors. Prices for forward delivery of all descriptions of finished steel continue to show an advancing tendency, and in steel bars and plates the premiums for prompt shipment have increased further. Regular prices given below are f.o.b. Pittsburgh, unless otherwise noted, the lower prices where a range is given being for delivery at mill convenience, the higher being for shipment within a few weeks.

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f. o. b. mill, except Colorado.

Plates, tank quality, 2.60c. to 4.00c.

Structural shapes, 2.50c.

Steel bars and bands, 2.50c., base; hoops, 2.75c., base.

Iron bars, Philadelphia, 2.559c.; Chicago, 2.15c.; Pittsburgh, 2.40c. to 2.50c.

Plain wire, 2.25c., base; wire nails, 2.40c., base; galvanized wire, 2.95c.; painted barb wire, 2.55c.; galvanized barb wire, 3.25c.

Non-Ferrous Metal Market

Tuesday, March 28.—The outstanding feature of the market is the strong situation in lead and the high prices being asked for spot and future deliveries by independents. Silver has also risen to the highest price in over two years. Other metals are substantially unchanged.

Copper.—The copper market has been quiet during the last two weeks and has fluctuated within very narrow limits. There has been very little buying. Offerings have been freer lately and there appears to be enough copper for sale to take care of any probable demands for the next two months. The market is firm, however, and there is no indication of any depression in prices. Spot electrolytic and lake are quoted at 27¼ to 27½ cents. April and May are quoted at 27 cents, and June and July at 26½ cents.

Tin.—The tin market has been somewhat relieved since the middle of March, owing to arrivals coming in at a faster rate. During the first half of March only 343 tons of tin arrived, and this is small compared with an average consumption of 2000 tons during this time. The demand since the middle of the month has been light, however, and as more tin was coming in, sellers shaded the price somewhat. This did not stimulate buying, however, and the price dropped to 50 cents for spot Straits tin on March 21. Since that time the price has remained steady at 49.50 to 50 cents, and the market appears to be firm, although very uncertain.

Lead.—On March 14, the Trust advanced the price of lead to 7.00 spot, New York. Lead is scarce and very hard to obtain, and while the Trust still holds to the price of 7 cents, independents are asking 7¾ to 8¼ cents and very little trading has been done owing to the small offerings. April deliveries are quoted at 8 to 8¼ cents by independents.

Spelter.—The demand for spelter, which was at a very low ebb during the first half of March, improved considerably for a few days, beginning at about March 15, and forced the price of about 18 cents for prompt western shipment. This activity was not sustained and the market has since become dull again, although the price still remains 17.60 for spot. Early deliveries are not freely offered, and the following prices are quoted at New York by the American Daily Metal Market, April, 17¼c.; May, 16¾c.; June, 16¼c.

Other Metals.—Aluminium remains in its strong position and is quoted at 60 cents. There has been very little change in the antimony situation and 45 cents is asked for both American, and Chinese and Japanese spot deliveries. Silver has risen to 60¾ cents and is now at the highest price since October, 1913. The falling off in Mexican production and a larger foreign demand are thought to be the cause for this advance. Platinum is quoted at \$88 per ounce and quicksilver at \$200 per flask.

A Proposed Plant for the Fixation of Atmospheric Nitrogen

Mr. Pierre S. du Pont, president of the E. I. du Pont de Nemours Powder Company, has addressed the following letter to Secretary of War Baker:

WILMINGTON, DEL., March 26, 1916.
Hon. Newton D. Baker, Secretary of War, War Department, Washington, D. C.

My Dear Sir: On frequent occasions during recent years General Crozier has called our attention to the menace involved by our dependence on foreign nations for our raw materials for nitric acid supply, this commodity being absolutely essential in the manufacture of smokeless powder and other explosives and in great demand as an essential in the manufacture of fertilizers. Several years ago the fixation

of nitrogen from the air by the use of the electric arc was found practicable abroad, and, with a view of implanting the industry in this country (solving our problem here at home), the du Pont Company sent a corps of its experts to Europe to thoroughly investigate the various processes there employed. As a result of these investigations the du Pont Company purchased the right of one of the leading processes used abroad, which process is now established in Europe on a commercial basis on a large scale of production.

As you know, the process of securing nitric acid from the air requires large units of hydro-electric power at a very low cost. Coincident with our investigations abroad, we have been studying the possibilities for satisfactory hydro-electric power in the United States, and we find that, while the power physically exists, it is not available because of Governmental restrictions. I inclose herewith for your consideration a tentative draft of a bill which we believe will protect the public interest and justify the investment of the capital essential to the solution of this problem in the United States. You will note the bill we submit provides that the company "shall deliver to the United States for military or naval purposes all or any part of the output of nitric acid at a price which shall include such profit as the Secretary of War shall determine to be reasonable."

With the way made clear, the du Pont Company stands ready to negotiate a contract under which it will begin the construction of a plant under such units and magnitude as may be agreed upon between the Government and the du Pont Company, the du Pont Company to furnish the capital. Should you desire to confer with me on any of the phases of this question I will be pleased to make a trip to Washington at your pleasure.

Very truly yours,

PIERRE S. DU PONT, President.

The process in question is the Birkeland-Eyde process, operated on a large scale in Norway. It is reported that the proposed plant would involve an investment of \$20,000,000. It is further reported that the proposed bill provides for grants or leases of power and dam sites in navigable streams or in the public lands for fifty years, the rates for power to be regulated by State commissions or by the Secretary of War in States where there are no such commissions. At the end of the fifty-year term, the Government is to have the option of taking over the plant upon payment of a fair value of the property, with no allowance for franchise value.

New Zinc Plant in Oklahoma

Mr. J. E. Hildt of Tulsa, Okla., well known in Oklahoma as an organizer of banks and a former railroad engineer and contractor, is about to build a new zinc retort plant. He has associated with him a practical zinc smelter man of twenty-five years' experience and also three prominent engineering specialists. Contracts for material, machinery and supplies are now being placed. A refinery making strictly high-grade spelter analyzing 99.92 per cent is to be started at once with a large initial capacity, "deriving its 99 per cent metal from ores whose geologic individuality will give the metal the proper physical properties."

A specially refined "Prime Western" and "Brass Mill Special" freed from dross by a simple process will be made later. Particular attention will be paid to making the slabs of uniform composition.

The ore that will be used is to be largely commercially desirable flotation concentrates. In the fall a lead plant to extract the gold, silver, copper and lead values is contemplated; also an acid plant utilizing the sulphur in the ore to make a 98 per cent sulphuric acid for oil refineries is contemplated.

The Washington meeting of the American Electrochemical Society (April 27 to 29) promises to be highly interesting. Dr. A. S. Cushman is chairman of the local committee. Thirty-six papers will be read and discussed. The full program will be printed in our next issue.

The Operation of the Blast Furnace

BY J. E. JOHNSON, JR.

Slags

This subject has received an enormous amount of study at the hands both of practical men and scientists, but particularly the latter. Much experimental work has been done upon the subject, but in my opinion by far the larger part of this has been entirely wasted because the kind of information needed has not been appreciated. The purpose of the slag is twofold. First: to remove in a convenient form the impurities of the charge which come from all three of its components, the ore, the fuel, and the flux, and render them fusible so that they may be removed from the furnace at the lowest possible temperature, since as I have many time reiterated, this is the critical temperature of the furnace, and as was shown in the article on thermal principles this is the point about which everything else revolves. Second: the slag must remove the sulphur which is always present in mineral fuel, and sometimes in the ore, so as to prevent its entering the iron. In a narrow sense this is only a subdivision of the broader subject of removing the impurities of the charge, but in practice and in the habits of thought which grow up from the operation of the furnace, these two functions are separate and distinct, and we may well consider them so.

Let me make clear here what I think has too often been not clearly stated in dealing with this subject.

Our knowledge of it is 99 per cent empirical. It is true that good furnacemen calculate the slag they desire to produce with some care, but they do it not according to any scientific law, or on the basis of any chemical formula, but simply to produce a slag which they know from experience will produce the desired result to the best advantage. In some departments of metallurgy it may be necessary to figure the oxygen ratio of slags, that is to say, whether they are bisilicates, monosilicates, or sesquisilicates, but in the blast furnace we not only may, we must, ignore all these considerations if we desire successful results. This is an extreme case of that general law that in the furnace we deal not with a chemistry of definite proportions but with an infinitely varying balance between two or more, generally many, contending forces, and we would be unable to detect in the plotted curve of our results, if we could make one, the slightest sign of a cusp indicating a critical point, or sudden change in the characteristics of the slag. If we know that an increase of 2 per cent in the silica in the slag will make a certain change in its character then we may be perfectly sure that the next variation of 2 per cent will produce a change in the same direction, and of approximately the same amount.

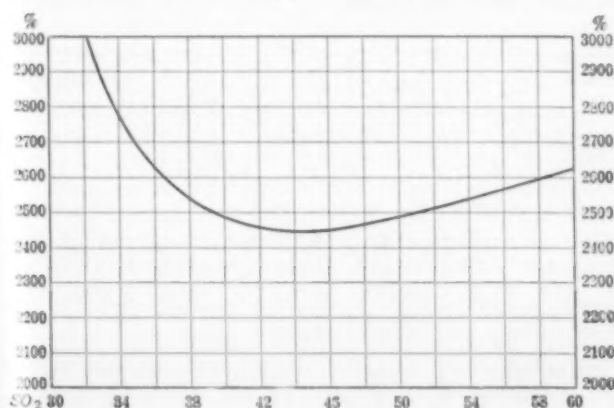


FIG. 1—TENTATIVE CURVE OF FREE-RUNNING TEMPERATURE OF ACTUAL SLAGS BASED ON OBSERVATIONS AND PYROMETER READINGS IN PRACTICE

The sketch diagram, Fig. 1, gives the free-running temperatures of slags having alumina virtually constant at 12 to 15 per cent with silica ranging from 33 to 60 per cent. This is not intended to be accurate, for unfortunately I have not the data to make it so, but represents the results of much observation and many hundred pyrometer readings on actual slags throughout the range mentioned.

In charcoal practice we have ordinarily no sulphur to consider. That contained in the fuel is very slight, probably well under a tenth of 1 per cent, and since the great advantage of charcoal as a fuel is its freedom from sulphur, and since it is possible to obtain ores and fluxes quite free from that impurity, such furnaces are commonly operated only with such materials, and under ordinary circumstances should never be operated in any other way.

In this case then we have to consider only the production of a slag with the lowest possible melting point to permit its removal from the furnace, so as to have the lowest critical temperature, and as we have already seen, this is the reason that charcoal furnaces are able to run not only with a smaller weight of fuel per ton of iron, but with a fuel only containing about three-fourths as much fixed carbon as is contained in coke. In charcoal furnaces then we are free to use virtually any slag which will accomplish our purpose best, or briefly, that which is the most fusible in the sense of having not the lowest melting but the lowest free-running temperature, and I have used slags which ran all the way from below 40 per cent silica up to almost 60 per cent in that element.

No refined means of measuring the fluidity of these slags was at hand, but observations were made with a pyrometer, and by eye, and as a result of long experience it was found that both of these extreme slags were less fusible than a slag ranging from 46 to 49 per cent silica, as indicated by Fig. 1. Accordingly in running for low-silicon iron a slag of the latter kind was used, but when high-silicon iron was desired a more siliceous slag was used, both because its hold on the silica was weaker, and therefore the latter could be more easily reduced and thrown into the iron, and because its free-running temperature was higher and therefore gave the somewhat higher temperature necessary to force the desired silicon into the iron. By both these means, therefore, we facilitated the introduction of the silicon into the iron with the least excess of fuel over that required for low silicon.

Turning now to coke furnace slags we have an altogether different condition. The sulphur in the fuel varies from about 0.3 per cent or lower in very exceptional cases up to 1½ per cent or 2 per cent in some cases, and in abnormally bad cases even higher than this, even up to 3 per cent. On the basis of a ton of coke to make a ton of iron this means in the average case that sulphur to the amount of about 1 per cent of the iron is present in the charge, and to obtain a merchantable product we must eliminate this at least to 1/20 of 1 per cent, leaving the sulphur in the iron 0.05 per cent or under, therefore 95 per cent of the sulphur must be eliminated. To accomplish this we have two principal means both of which are accomplished simultaneously by one charge in the burden. We must increase the bases, generally the lime, in the charge, over what we use in charcoal practice.

The lime divides itself between the silica and the sulphur according to some law which has never been worked out, but in general the more basic the slag the more ready it is to satisfy itself with sulphur, and increasing its basicity has the effect also of increasing its fusion temperature; and this, by increasing the reducing action of the furnace, exerts a more powerful ac-

tion on the lime to reduce it to calcium sulphide, and thereby further increases its activity for desulphurization. But here we work under very different conditions from those which prevail in charcoal practice, because we come now to the fact that the change in fusibility of the slag toward the two ends of the range mentioned is very different, due to the fact that some slags are "short" and lacking in viscosity, like water or mercury or light oils, whereas others have a long viscous range like molasses or tar. They begin to soften and are no longer solid at temperatures far below those at which they can in any proper sense be called liquid and become liquid far below the temperature at which they become free-running.

The limey slags in a general way belong in the former class, whereas the silicious slags belong in the lat-

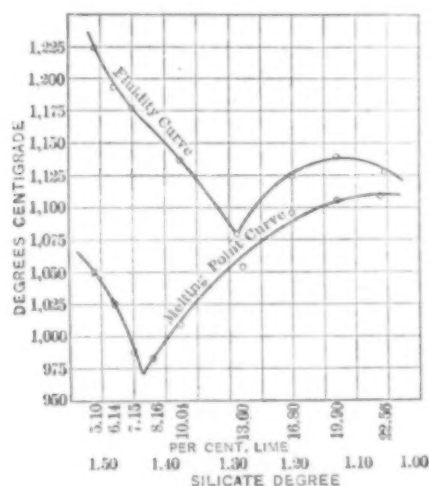


FIG. 2—MELTING-POINT CURVE—FLUIDITY CURVE

ter class. To illustrate this; if a limey slag be poured from a hand ladle it falls in little round pellets, almost like shot, which are individual drops when they strike the ground and when still red hot, whereas a silicious slag under the same conditions does not produce pellets but long strings, or if a little puddle of it be poured this will remain connected with the ladle by a string, and even when it is apparently almost cold this string can be drawn out like glass to great lengths.

This is probably one of the most important facts of furnace operation. For as has been so often reiterated, the important point is the free-running temperature of the slag, and with a limey slag it is only a few degrees from its softening point to the point where it runs freely, whereas with a silicious slag on the other hand this range is 200 or 300 deg. Although some work has been done along this line, exact data in regard to iron blast furnace slags on this basis have never been published, but Professor Fulton of the Case School of Applied Science published before the American Institute of Mining Engineers in 1912, a paper on "Copper Blast Furnace Slags," in which this point was well brought out, and from which Figs. 2 and 3 are reproduced. It will be clearly seen that the range between the free-running temperature shown by the upper line and the softening temperature shown by the lower one varies enormously. It is this fact which has done so much to minimize the value of investigations by scientists on this subject.

It is comparatively easy by making slag-forming materials into cones and observing the point at which the tip of the cone begins to deform to determine their softening point, but it is exceedingly difficult to determine their free-running temperature. The suggestion

of W. McA. Johnson to do this by timing the discharge of a given weight of slag at different temperatures through a standard-size hole in the bottom of the crucible containing it, is the best of which I have knowledge. I have suggested as a method of standardizing the orifice that the free-running temperature of an actual slag be taken at the furnace, and then that size of the orifice determined by experiment through which a given quantity of this slag at this temperature would run in a given time. The temperature at which any other slag would run through the same orifice in the same time would be its free-running temperature. It seems lamentable that with the facilities for doing this work possessed by modern colleges and universities, nothing has ever been done along this line, although it would go further than anything else to solve the practical problems of blast furnace operation.

The difference between coke and charcoal practice consists not only in the fact that the critical temperature in the latter is lower, but also in the fact of almost equal importance that in charcoal slags we are free to choose the flat range along the bottom of the curve of Fig. 1, and a variation either way does not affect the operation of the furnace very materially. But to secure the desulphurization required with low-silicon coke irons a ratio of lime to silica of about one and a half to one is necessary which is reached at approximately 34 per cent silica. It will be seen that this is on a decidedly steep portion of the curve; the result is that a slight change in the ratio of the lime to the silica has a great influence.

If the silica rise to 37 per cent, the ratio of lime to silica is only 1.35 to 1 and we are likely to have insufficient desulphurization, which in plain language means high sulphur or generally an unmerchantable product, while if the silica fall to 32 per cent, the critical temperature rises on the basis of this sketch diagram about 250 deg. Fahr., with a very serious effect on the operation of the furnace because we have not only the increased critical temperature and the consequent rapid diminution of hearth heat as shown by the chart in the article on thermal principles, but we have a decided increase in the amount of slag to be melted.

If the silica be reduced from 34 per cent to 32 per cent by increasing the lime, this involves an increase of 6 per cent in the total volume of the slag, and the increased hearth heat required for this added to the diminution of hearth heat produced per pound of fuel by the increase in the critical temperature quickly uses up any reserve of heat the furnace may have.

Failing sufficient hearth heat, the slag is no longer heated to its free-running temperature but becomes stiff and inactive; the iron is unable to free itself from the slag and heavy losses of iron occur, while on ac-

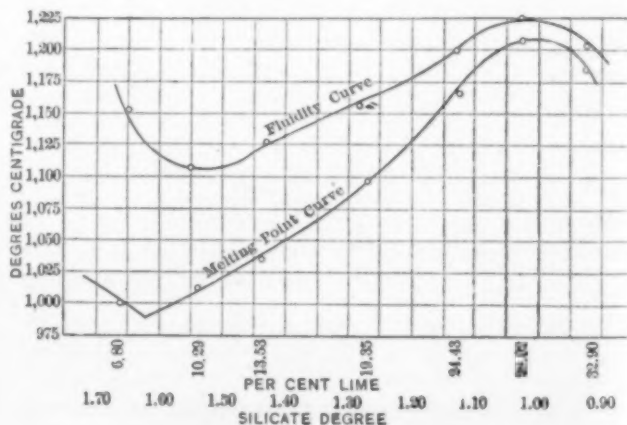


FIG. 3—MELTING-POINT CURVE—FLUIDITY CURVE

count of its lack of fluidity the slag is unable to desulphurize the iron, in which therefore the sulphur rises not infrequently to several times the permissible limits and the iron thereby becomes entirely unmerchantable. If this condition endures for more than a short time without obtaining relief from additional fuel or additional blast-heat the slag is likely to become so stiff that it can no longer be withdrawn from the furnace and the interruption to operation which results may last from twelve hours to many days.

Before this chain of events was thoroughly understood, and especially before it was realized that if the percentage of lime exceeded a certain amount, the desulphurization became worse and not better, because the stiffness of the slag more than outweighed its greater basicity, furnaces were frequently "lime set," that is, reached the point where the slag became nearly or quite infusible, and freezing up around the walls of the furnace prevented the iron from being withdrawn on one hand, and the ingress of the blast on the other. Stopping the supply of blast resulted in stopping the combustion of the coke and the generation of heat; this, of course, quickly exaggerated a condition already very serious and the furnace became entirely frozen up. In more than one case when the furnace was watered down preliminary to shoveling out, the quantity of lime in the hearth under these conditions was so great that it burst the structure. Many such cases have occurred in quite recent years and even down to the present time furnaces not infrequently come perilously close at least to the early stages of this condition.

It will be seen, therefore, that a coke furnace must be driven along a narrow path like that on the side of the mountain. If we deviate from the course on the upper side our progress is stopped and damage may result. If we go too far the other way we plunge to destruction at a rapid rate.

The elements with which we have so far dealt are particularly the lime and silica, the latter being the principal impurity, as well as the most acid in its action, which we have to flux out, and the former the base by which this acid is both neutralized and fluxed. The sulphur, as pointed out in the article on chemical principles, is present as calcium sulphide, a neutral substance, and not to be regarded either as an acid or a base. We have, however, other ingredients to consider, of which by far the most important in quantity and effect is alumina.

MAGNESIA AND ALUMINA

The effect of alumina has been a matter of vigorous dispute. Many furnacemen have been accustomed to consider it as an acid, and adding it to the silica, to consider the two jointly as "total acids." A few, on the other hand, have claimed that alumina, being the oxide of a metal, was necessarily a base, and as such have added some portion of it to the lime and magnesia.

Considering these opposite contentions, I began to believe a good many years ago that it was neither one, but acted only as a neutral addition, affecting the physical condition of the slag, but not affecting its viscosity or acidity to any important degree. This view was set forth by me in a paper before the American Institute of Mining Engineers in 1912, part of which is quoted as follows:

We may as well dismiss the obscurity which comes from the introduction of oxygen-ratios and other abstruse theoretical considerations, and admit frankly that experiment on the furnace itself is the only safe foundation for practice or for a useful theory.

I am moved to lay stress on this point, because in years past I was greatly puzzled and befogged by some

of the older school of furnacemen, who emphasized the mysterious nature and difficulty of making slag calculations, the fact being that, given the materials to be used and the slag to be produced, the college student who could not be taught in a day to make the calculations would have a poor chance of ultimate usefulness. The omission or concealment of the fact that the slag to be produced was known only by experiment and experience with the furnace itself caused my mystification, and I therefore emphasize it here.

The object to be sought may be briefly stated as follows:

Given the materials to be used and the kind of iron to be made, to ascertain the slag which will produce the results with the least cost for coke and for flux and will permit the greatest output. The three desiderata come in the order given.

We may in this discussion omit consideration of charcoal practice because the slag question is of minimum importance in that field, and the field itself is of minimum importance in the iron industry. Also because of my complete ignorance of that practice. (This paper was written three years ago, but has remained unpublished until now. It so happens that in the interval I have had extensive experience with charcoal-iron slags, but it is not considered desirable to introduce a consideration of that subject into this paper, because in the absence of the necessity for desulphurization the problems offered by charcoal slags are totally different from those of coke slags. In a general way, however, it may not be amiss to state that observation of charcoal slags has confirmed the position taken in this paper.)

Coming then to normal coke practice, and remembering that generally the lowest fuel consumption is obtained with the lowest critical temperature, the object desired may be stated more definitely as the production of the most fusible slag that will give the necessary desulphurization of the iron. This statement is, perhaps, subject to certain limitations from the fact that there are circumstances in which it is necessary to raise the critical temperature in order to enable the iron to absorb a large quantity of silicon.

The desulphurization effect of the slag is proportional, not only to its basicity, but also to its fluidity in an almost equal degree, so that while increased lime *per se* has a desulphurizing influence, this is to an increasing extent neutralized, and finally reversed completely, by its decreased physical activity.

This is well shown in basic practice, in which the highest sulphur iron is made, not with deficient lime but with an excess (due to a change in ore or the like) so great that the heat available is unable to bring the very refractory slag to the free-running condition necessary for proper desulphurization.

In further illustration of the point, there are two distinct methods of making this kind of iron. The first consists in running on a very calcareous slag, with which the silicon in the iron is kept down by the basicity of the slag in spite of the high temperature necessary to keep the latter fluid. The second consists in maintaining a slag of only moderate basicity and much lower fusion temperature, and keeping down the silicon by carrying a heavy ore-burden, which, of course, can easily be done with the lower critical temperature.

Furnaces running on the first plan always require more coke for basic than for foundry iron, while those running on the second plan use less than for foundry iron.

It seems to me practically certain, therefore, that there is a considerable range of lime content in the slag for given conditions, in which the desulphurization of

the iron is not appreciably affected, while the coke consumption necessarily rises with the increase in the fusion temperature consequent on the higher lime ratio, as well as the increased slag volume.

In all theoretical slag calculations the quantity of magnesia is multiplied by 1.4 to put it on the same basis as the lime, which, from the point of view of the oxygen ratio and molecular weights, is perfectly correct. Practically, however, this does not work out. Furnacemen using a limestone with a variable content of magnesia have told me that careful observation had failed to show any difference whatever on the furnace, whether the magnesia was high or low, and I have seen a furnace using half calcite and half dolomite, the calcite being relatively impure and the dolomite very pure, put onto all dolomite, which should have made the slag excessively basic, on the basis of molecular weight, but which, as a matter of fact, showed no observable change.

The truth seems to be that magnesia is less active chemically than lime in about the same proportion that its molecular weight is less.

An interesting proof of its small chemical activity is supplied by the manufacture of caustic soda from the carbonate. Quicklime is added to the carbonate solution, and takes up the carbon dioxide from the soda; for this purpose magnesia is found to be perfectly inert and worthless. Sir Lowthian Bell's opinion that magnesia was so inert as to be useless for the removal of sulphur in the blast furnace is well known, but this opinion is no more borne out by practice than that giving it a greater value than lime, the truth appearing to be that for furnace purposes, in all ordinary proportions, one is about as effective as the other.

It is very necessary, however, to recognize that the addition of a certain amount of magnesia has a marked effect in lowering the fusion temperature of the slag, and is therefore of great use where calcareous slags are required, particularly in the manufacture of basic iron.

For practical purposes lime and magnesia may be considered as being of equal value, and hereafter in this paper "lime" will be used to mean the sum of lime and magnesia.

THE EFFECT OF ALUMINA

The foregoing portion of this paper contains nothing essentially new, and is intended as an introduction to the remaining portion, the substance of which seems to have been unknown to most of the furnacemen with whom I have discussed the subject.

The effect of alumina has been the subject of much discussion; some regard it as an acid, others as a base, while a few declare it can be made to act as a base or an acid almost at will.

It has seemed to me that under such circumstances the probability was that its action was neither acid nor basic, but was perfectly neutral, simply a diluent affecting the viscosity of the slag to some extent, but, with a given ratio of lime to silica, not affecting its chemical nature at all.*

For several years the range of alumina in slag of which I had knowledge was so limited that I could not prove this contention, but very recently a furnaceman gave me complete information of a remarkable series of experiments he had carried out, in which the alumina

in the slag had been so high as 39.5 per cent with silica as low as 21 per cent on individual flushes, and averaging for an entire day SiO_2 , 24.7; Al_2O_3 , 36.0 per cent.

The iron made was good Bessemer iron, about 2 per cent of silicon, with sulphur about 0.023 per cent.

With this let us compare standard Lake-ore slag on basic iron running about Al_2O_3 , 13.5; SiO_2 , 33 per cent, and Virginia slag on the same iron, Al_2O_3 , 6.5; SiO_2 , 36 per cent.

It is unfortunate that the experimental run was on Bessemer instead of basic iron. The records of other days, which show basic iron made, are not so complete, but they indicate only a small difference in the slag, that shown, of course, being an increase in lime.

The coke consumption of this slag was not materially different from what it was in standard practice; the slags were free-flowing, and did not have a noticeably higher fusion temperature than ordinary.

Here, then, we have three cases, in all of which the coke is of about the same sulphur content, the desulphurization of the iron is the same, the coke consumption is no more different than would be accounted for by the different kinds of ore. The only difference of importance is the silicon in the iron, which is not sufficient to require a very great change in the slag composition. We will refer to this condition later.

The amount of lime in these slags can be determined by subtraction, but it is necessary to remember that there is a small quantity of neutral material, CaS , FeO , MnO , etc., which may be taken at 3.5 per cent in all cases as a close approximation to good practice. Following this procedure, the results shown in the first four columns of Table I are obtained:

TABLE I—COMPOSITION OF SLAGS.

1	2	3	4	5	6	7
Al_2O_3	SiO_2	CaO by Difference	Neutral Substances	Ratio CaO	Ratio $\text{CaO} + \text{Al}_2\text{O}_3$	Ratio CaO
per Cent	per Cent	per Cent	per Cent	$\text{Al}_2\text{O}_3 + \text{SiO}_2$	SiO_2	SiO_2
6.5	36.0	54.0	3.5	1.27	1.68	1.50
13.5	33.0	50.0	3.5	1.08	1.92	1.51
36.0	24.7	36.8	3.5	0.59	2.90	1.44

Columns 5 and 6 present the ratios of lime to silica + alumina, and lime + alumina to silica. These ratios change from 1.27 to 0.59 in the first case and from 1.68 to 2.90 in the second case.

No one can hope to show any relations between these ratios that can bear in any intelligible way on the variation of the alumina content.

Column 7, however, shows the ratio of the lime to the silica, which is virtually a constant throughout. The result in the experiment is the lowest, and corresponds to the higher silicon in the iron.

If the lime were increased in this latter case about 5 per cent of its own weight, this slag would then have identically the same ratio as the others, and would be just about as much "limier" as would permit the production of basic iron by the addition of a little more burden.

It may be claimed in opposition that the analyses chosen as representative of Virginia and Lake-ore practice have been taken with the object of showing the result desired rather than representing the typical slags. For the Virginia practice this certainly is not true, and if there be any error in the slag-analysis for Lake ore, I do not know how to better it. Certainly no correction that could be made would fail to leave the lime-silica ratio infinitely nearer a constant than either of the others.

It may be well to reiterate here that such a comparison is only useful in the case of furnaces on a comparable basis in other respects; that is to say, working for the same degree of desulphurization and the same sili-

*This conception of a given constituent affecting the physical but not the chemical properties of slag, in which two kinds of properties are so closely interwoven, is difficult at first sight, but I have illustrated it for myself as follows: If we had an ordinary acid, such as hydrochloric acid, in one beaker, and a solution of caustic alkali in another, we could mix the two in any proportions and each addition of one or the other would result in a corresponding change in the acidity or basicity of the resultant solution, but if we added a considerable quantity of molasses, we would alter its viscosity and its "free-running temperature," without affecting its chemical properties in any way. The illustration is a homely one, but in my opinion the case is precisely parallel to that of slags.

con, and using materials of about the same sulphur content.

The question of the slag volume also enters here, and the question whether a given slag volume is as efficacious in the removal of sulphur when the alumina is high as when it is low. We know that if the slag exceeds a certain content of sulphur in ordinary practice, the desulphurization of iron will be incomplete, and if the alumina be simply a diluent, the effectiveness of the slag might be diminished in proportion as the percentage of the alumina rose.

In spite of this theoretical consideration, the sulphur in the slags in the high-alumina experiments mentioned ran about 1.75 per cent with perfectly satisfactory desulphurization, while the relative slag volume was little, if any, higher with alumina approaching 40 per cent than with normal alumina.

The decreasing grade of the ores available must result in the increasing use of many ores higher in alumina than those of present practice. If the laws governing its action are not known bad results are bound to follow.

A furnaceman recently told me of a case in which the alumina had been regarded as an acid, and the slag had been calculated to give the same ratio of lime to silica + alumina as in standard practice, with the result that the furnace had been badly "bunded up" with lime.

In conclusion, it seems worth while to point out that the increased viscosity accompanying high alumina may be of benefit in making foundry iron. This was a subject to which both Mr. Frantz and I independently had given some consideration for several years.

That iron will not take up much silicon except at a relatively high temperature is well known, and as its melting temperature is relatively low, its tendency is to run down out of the region in which it can absorb silicon into the crucible.

The fusion temperature of slag is much higher than that of iron, and being more viscous, it acts as a retardant on the iron and delays its descent so that it can acquire the necessary temperature.

A too-fusible slag does not perform this function properly, and I have personally seen a case in which no reasonable reduction of burden would raise the silicon to ordinary foundry limits, but in which this was easily done by increasing the lime considerably beyond that necessary for desulphurization, in spite of the desiliconizing influence of the more basic slag. For the same reason it is more difficult to make foundry iron when enough magnesia is present to increase the fluidity of the slag.

Now if alumina increases the viscosity of the slag without the accompanying desiliconizing influence of the limier slags of the same free-running temperature, then the introduction of the silicon into the iron should be facilitated by high alumina.

It is six years since this paper was written though only three since it was published. In that interval all my experience has gone to confirm the opinions expressed therein, both as to the general effect of alumina and as to the entire possibility of using this element as a means of raising the free-running temperature of the slag without increasing its basicity, for the manufacture of high-silicon irons.

In very recent years a vast amount of work has been done under the auspices of the Carnegie Institution by G. A. Rankin, A. L. Day and E. S. Sheppard upon the melting points of the ternary system $\text{CaO}-\text{Al}_2\text{O}_3-\text{SiO}_2$. Through the courtesy of Mr. Rankin I have obtained a copy of his paper bearing that title published in the *American Journal of Science*, Vol. XXXIX, which gives the results of these investigations. These are plotted on the triaxial diagram, and from the plot an actual model was constructed, photographs of which, reproduced from Mr. Rankin's paper, are shown at Figs. 4, 5 and 6.

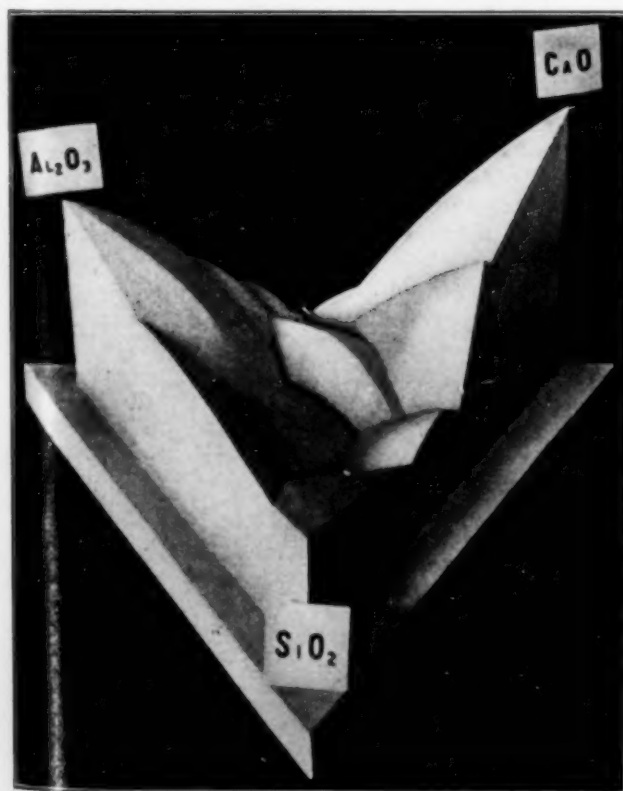


FIG. 4—PHOTOGRAPH OF SOLID MODEL OF CONCENTRATION-TEMPERATURE DIAGRAM OF TERNARY SYSTEM; SHOWING RELATION OF BINARY SYSTEMS $\text{CaO}-\text{SiO}_2$ AND $\text{Al}_2\text{O}_3-\text{SiO}_2$ TO THE TERNARY SYSTEM

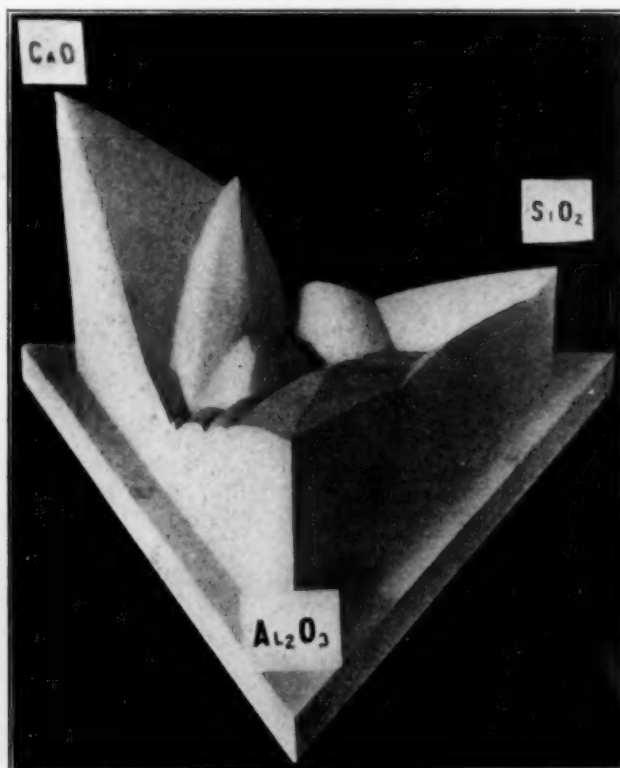


FIG. 5—PHOTOGRAPH OF SOLID MODEL, SHOWING RELATION OF BINARY SYSTEMS $\text{CaO}-\text{Al}_2\text{O}_3$ AND $\text{Al}_2\text{O}_3-\text{SiO}_2$ TO THE TERNARY SYSTEM

Before discussing these results it may be well to call attention to the characteristics of the triangular diagram. They are based upon the fact that in an equilateral triangle the sum of the perpendicular distances of an interior point from the three sides is a constant, and therefore the composition of any substance made up of three components may be graphically represented by the position of a point whose distances from the respective sides are represented by the percentages of the corresponding components. Each angle of the triangle represents one component unmixed with anything else. Any point on one side represents a compound consisting solely of the two materials represented by the two ends of that side without any of the third component, and the percentage of this third component increases in proportion to the perpendicular distance from this line. This explanation, with a little study of the diagrams will give a clear understanding of the principle involved.

This enables us to plot the proportions of the three fundamental variables on one plane, and therefore to plot any independent function of all these upon ordinates vertical to that plane. The surface passing through the tops of these ordinates furnishes a graphic representation of the variation of the independent variable with changes in the composition of the material under consideration.

This diagram in three dimensions was first used, as far as my information goes, by Prof. R. H. Thurston in the middle seventies to portray the results of an extensive investigation of the properties of the copper, zinc and tin alloys.

This form of model has been used more or less for slag diagrams and slag calculations for a number of years. Various references to it may be found in technical literature, notably in the Transactions of the American Institute of Mining Engineers.

A study of the photographs of Rankin's melting point model shows, first of all, what may perhaps properly be called a general law of nature, that the admixture with a given substance of a small amount of another substance always results in lowering the melting point, since a study of the different views of the model shows that in every case it slopes from the angles of the tri-

angle down, and from the sides, in practically every case, it slopes downward toward the center, thus forming a sort of rough crater with high walls along the sides and much higher peaks at the apices of the triangle. The different ridges and valleys in the diagram are caused by the occurrence of different definite chemical compounds. These are indicated by Fig. 7.

This investigation is one of the most elaborate ever made, and is distinguished from most others, whose results were useless, by the fact that great pains were taken to secure not softening points, but complete liquefaction or melting in every case.

This diagram while interesting from the furnace-man's point of view is difficult to use because the range of alumina commonly and preferably used in furnace practice is only from 5 to 15 per cent, which confines us to quite a narrow belt parallel to the $\text{CaO}-\text{SiO}_2$ side, and within this belt we are further limited to the ratios of lime to silica, which we are permitted to employ especially in coke furnaces.

In order to make the result of this vast scientific work applicable to blast-furnace purposes at least in some degree, I obtained through the great kindness of Mr. Rankin three curves representing sections of the model along the planes of 5, 10 and 15 per cent alumina. These curves have all been plotted on one diagram, Fig. 8, so as to make them comparative. The silica is taken as the independent variable, the alumina is constant on any one curve, and the lime may be obtained by subtracting the sum of the silica and alumina at any point from 100. The curves terminate at different points because obviously in the one representing 15 per cent alumina the silica must be limited to 85 per cent, while in the one representing 5 per cent alumina the silica can go to 95 per cent. Hence the right-hand limits of the diagram are not coterminous.

It will be seen that the diagram contains two sets of lines; the lower one is made up of short sections of vertical and horizontal straight lines, which show that the softening temperatures of the different compounds remain constant over quite wide ranges and then change by sudden jumps, while the changes in the temperature of complete fusion take place along continuous curves, although these latter contain three prominent cusps.

I have added to this diagram a reproduction of the curve shown in Fig. 1, which gives, as already described, my idea of the free-running temperatures of different

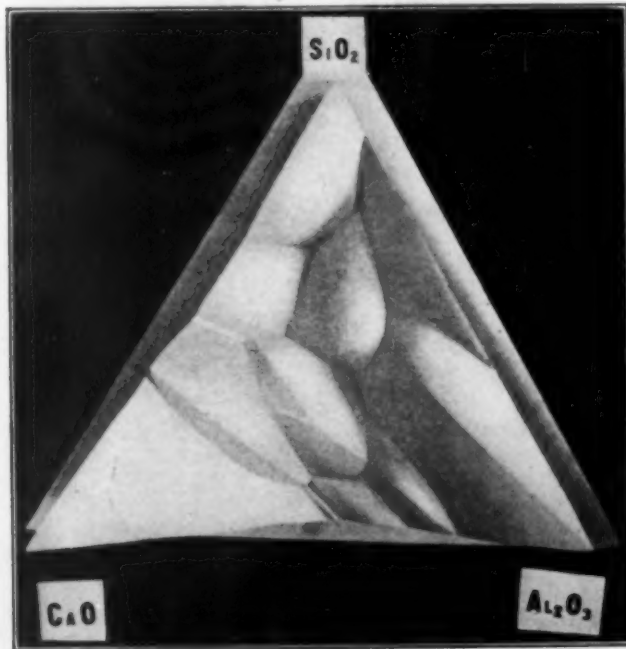


FIG. 6—PHOTOGRAPH OF SOLID MODEL TAKEN FROM ABOVE, SHOWING RELATION OF VARIOUS FIELDS

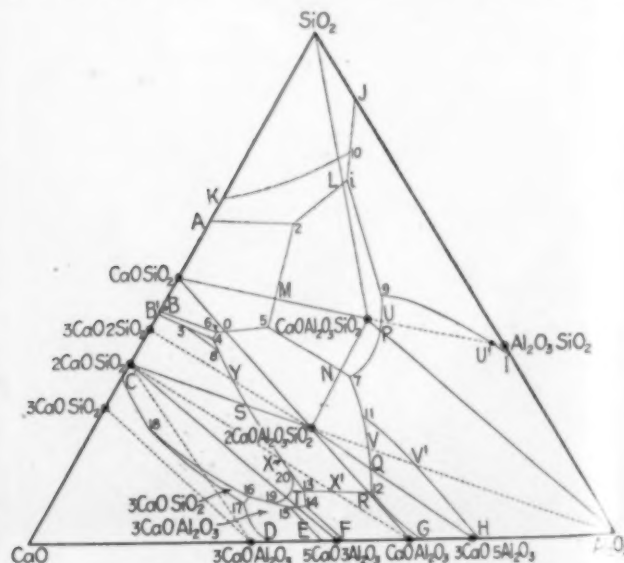
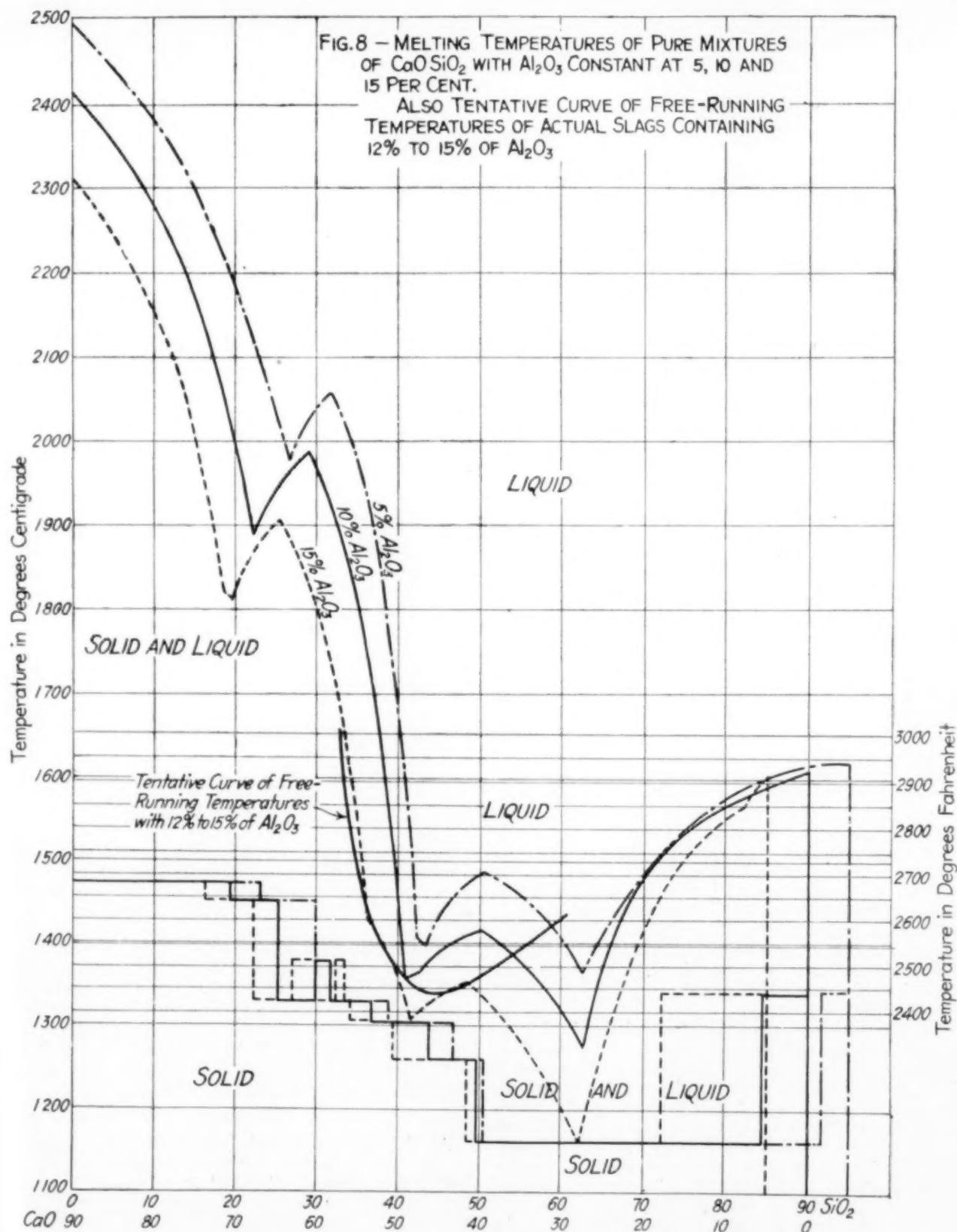


FIG. 7—DIAGRAM OF THE TERNARY SYSTEM, SHOWING THE VARIOUS BINARY SYSTEMS WITHIN TERNARY SYSTEM



slags containing about 15 per cent alumina with different percentages of silica, this curve being drawn as a result of observation and experience, with some pyrometer readings, covering a great many years, but on purely commercial slags always containing other ingredients besides the three represented in the diagram; notable among these are magnesia, calcium sulphide, manganese and iron.

Considering that my curve was laid down simply in

accordance with my experience, and entirely without reference to the correct scientifically derived curve of Mr. Rankin, its agreement with the curve for 15 per cent Al_2O_3 is in my judgment quite remarkable. The fact that it lies in part below the Rankin curve, although it represents free-running temperatures while the Rankin curves give melting temperatures, may be explained either by my being in error or, as I prefer to believe, by the presence of the other ingredients men-

tioned above, magnesia, calcium sulphide, etc., which lower the melting point.

Assuming the reasonable correctness of my curve for free-running temperatures, the tremendous variation in the range between these and melting temperatures is well shown.

It will be noted that the low point corresponding on all the curves to about 62 per cent silica is not reflected in my rough curve. I do not think that I ever ran a furnace on a slag containing more than 56 or 57 per cent silica in charcoal practice, but I have run on one containing that amount. I have heard of others who have run furnaces on even leaner slags, containing up to 63 per cent silica, but I have never heard that they noticed particular fusibility in that region. On the contrary, my own experience and that of others with whom I have talked concerning this little-known subject has been that these slags tended to make a hotter iron than one lower in silica. This is, in my judgment, for the reason that the increase in viscosity due to the higher silica more than compensates for the lower melting point.

I have noticed, however, in charcoal practice that slags of 49 to 51 per cent silica, with about 12 per cent alumina, were distinctly less desirable than slags of somewhat lower silica, which may very well correspond to the high point occurring on all three melting-point curves at or very close to 49 per cent silica. As a result of this fact, I usually preferred to burden the furnace to produce a slag of 46 to 48 per cent silica.

As a result of general observation I should say that the slags from 50 per cent silica up were fusible at a lower temperature than those below that point, but as this fusibility was not of a kind which could be translated into free-running temperature it was not a matter of much moment; in fact, the free-running temperature of the slag in charcoal practice, especially with wet, rich ore, is immaterial, since we have seen that the limitation to fuel economy comes not from a deficiency of hearth heat but from a deficiency of shaft heat. This fact was reflected by the circumstance that we could change the lime-silica ratio of the slag over a very wide range without particularly affecting the fuel economy of the furnace. But the free-running temperature of the slag was of importance because it was quite generally believed that better iron could be made with more fusible slags. The belief, though rather vague and shadowy, was entirely justified by knowledge which we subsequently obtained as to the conditions controlling the quality of charcoal iron, all of which will be explained later.

The range between the scientifically determined melting-point curves and my approximate curve based on experience, which begins to increase at 50 per cent silica, corresponds precisely to the varying range between melting points and free-running points shown by Professor Fulton's curves. It will be noted that leaving out the two downward cusps due to the formation of definite compounds with a low melting point at 41 per cent and 62 per cent silica, the general course of my rough curve follows in a general way the scientifically determined melting point curves; that is to say, the left-hand limb of the curve is very steep, the bottom section approximately horizontal, it then rises again on the right, but much more slowly and to a much smaller height, within any practical limits than the left-hand limb.

In similar wise it will be noted that each increase of alumina, from 5 to 10 and from 10 to 15 per cent, corresponds to a distinct lowering of the fusion point throughout the entire practical range of furnace slags, but this again does not correspond to the facts of prac-

tice, and I think for the same reason the increase in viscosity contributed by the alumina raises the free-running temperature of the slag above its melting temperature by an increased range equal to or greater than the reduction in melting temperature due to the presence of the alumina. This is partly contradicted by one experience of which I have heard. In that case the furnaceman considered that his alumina was too low for good work, and when it fell to about 10 per cent it was deliberately raised by the addition of a more aluminous mixture. This, however, was on an old and badly worn furnace, and on a new furnace with good lines the same tendency did not manifest itself. The furnaceman concerned, who gave me this information, did not seem to feel very positive that he had either proved or disproved anything very positively in regard to this. On the other hand, I have had some experience which leads me to believe that low alumina is really beneficial, even though that fact may contradict the results shown by Mr. Rankin's diagram, for the reason that he determined melting points, whereas the best furnace is concerned only with free-running temperatures.

Mr. Gilbert Rigg of the New Jersey Zinc Company has done an immense amount of research work on slags, and has very generously discussed some of his results and conclusions with me.

His work has tended strongly to confirm my conclusions as to the marked difference in range between melting and free-running temperatures with different slags, and the decided effect of this difference in altering the physical action of the slag.

Mr. Rigg has suggested that when the slag is relatively acid, alumina acts as a base and partly masks the effect of the acidity, but when the slag is relatively basic the alumina tends to combine with magnesia and forms a magnesium silicate known as spinel, which is exceedingly infusible and by its presence very markedly stiffens up the slag.

Moreover, Mr. Rigg states that magnesia and alumina when brought out into intimate contact far below the fusion temperature of either or of the resulting compound form a spinel. Such an action can only have the most serious result in the slag finally formed, and is probably responsible for the bad repute as a flux in which magnesia was held by some furnacemen, especially those of an earlier generation. There was a very general opinion at one time that the formation of spinel led to the building up of the hearth and all the bad consequences of that action. It is quite likely that this did occur in some cases, but I have no definite knowledge of the circumstances, and it does not seem to constitute a serious danger in modern practice. The subject of spinel, like the whole subject of slag, is one concerning which but little is known, or if known the knowledge is not generally available.

GAS IN SLAG

All slag seems to contain a large quantity of gas, not in the form of bubbles, for these are often entirely absent, but presumably dissolved or, as we say to conceal our ignorance of the real conditions, "occluded." This gas may be seen passing off from the slag in large volumes as it runs from the furnace, but is most conspicuous when a ladle of molten slag is quickly dumped; a great cloud of gas is evolved from the running surface of the slag and ceases as soon as the slag ceases to flow, usually in a few seconds. This occurs when the slag is dumped on the dry clean surface of the slag last dumped, and so cannot be caused by the presence of any foreign matter.

It is worthy of note that the gas evolved partakes of the nature of the top gas being produced at the time.

If the furnace is working hot and well, the top gas is white and heavy, so also is the gas evolved from the slag; when the furnace is working "raw" or cold, the top gas is thin and clear, and the gas from the slag is the same.

No satisfactory reason for these changes in the top gas has ever been given so far as known to me, but the relation of cause and effect between the maintenance of the critical temperature of the slag and the proper work of the furnace, on one hand, and between the proper working of the furnace and the nature of the gas, on the other, is so close that one is led to suspect that the fume which gives the gas its thick white appearance is a product of a slag at its proper temperature, and that the gas evolved from the slag is simply a portion of the hearth gas dissolved in the slag. That this gas is combustible is clearly shown by its often burning when a small jet of it comes out through a crack in the pot, though the gas evolved at the time of dumping does not burn.

No considerable investigation of the nature and cause of this gas has ever been made so far as I know, but Mr. Rigg has suggested a very interesting possible result of its presence, which is that the presence of this gas may have a decided effect on the fluidity of the slag. Certainly it is true in a general way that the most fluid slag evolves the most gas.

Mr. Rigg has reinforced this suggestion by citing the case of certain finely divided solids which, when heated, act exactly like liquids as long as they contain any "occluded" gas, but become simply hot granular solids when this gas is all driven off.

As an illustration and confirmation of the broad principles of the nature of slags above set forth there may be cited the following case which came within my experience:

About 1894, when the basic open-hearth furnace began its period of rapid development in this country, a sudden demand sprang up for what has since come to be universally known as basic iron; that is, iron suitable for this process. On account of the severity of the chemical specifications a small premium was offered over the price of mill iron, whose place it took, and the times being exceedingly hard, most furnaces selling iron below the cost of production, the incentive to earn the premium and make this iron was very great.

It is, I believe, generally admitted that the Longdale Furnaces were the first to make this iron in such a way that a very large percentage of the total output came within the chemical specifications of silicon under 1 per cent, sulphur under 0.05 per cent. Other furnaces which made it in those early times ran the best they could under the conditions tending to make the desired product, picked out the suitable irons, and either sold the other at a reduction in price or remelted it.

At Longdale it was at first attempted to make this iron with the use of straight calcite or limestone as a flux, but the destruction of the furnace walls by the extremely basic and infusible slags so produced was very rapid and made the operation difficult and unsatisfactory. Steps were then taken to secure a supply of dolomite containing almost the theoretical percentage of lime and magnesia, and this was substituted for half the limestone in the charge. The result was almost instantaneous. The trouble with the eating away of the furnace walls ceased, and it became possible to run the furnaces regularly and continuously on iron of the specifications given, and it is probable that no furnaces ever exceeded the records of those furnaces in the percentage of good basic iron produced for many years thereafter. It is a matter worthy of remark that one furnace ran for a whole six months without making a

single "off-cast." The reason for the success of these furnaces in making this iron was for many years a matter of speculation among iron and steel people. A part of it was undoubtedly due to the fact that not having high-blast heat available, nothing beyond 850 deg. Fahr., they ran on the high-burden low-temperature basis, and having iron pipe stoves, at an extremely regular blast temperature.

A further factor in addition to the above, all of which has been the subject of previous comment, is the fact (so far as I know never noted in this connection before) that these furnaces ran on an ore very low in alumina and quite high in silicon, so that the alumina in the slag was only about 7 per cent. Owing to the low viscosity of the slag, this tends to produce an iron considerably lower in temperature than the slag, the retardant action of the latter being reduced to a minimum. This fact I confirmed by pyrometric observations made many hundreds of times.

These furnaces, therefore, had for the making of this iron these advantages: the correct principle of manufacture, high burden and low lime, the correct or approximately correct proportion of lime or magnesia in the slag to give the lowest fusion point, very low alumina content to produce a short non-viscous slag, and so avoided superheating the iron.

THE LOSS OF IRON IN THE SLAG

The slag losses of iron are of two kinds. First, iron chemically contained by the slag as a low oxide; second, fine shots of metallic iron mechanically suspended in the slag, and so small that their difference in specific gravity is not sufficient to make them settle out in the time available for that operation. This loss is considerably greater than is usually appreciated. It is probably safe to say that no furnaceman has ever taken up the subject either to investigate the matter or to recover the iron who has not been surprised at its amount.

A few years ago when operating a charcoal furnace from which the slag was crushed and used as road material, I found that between one and two-tenths of 1 per cent of the weight of the iron were recovered in pieces picked out from the streets. A magnetic separator was installed in the expectation of being able to recover this amount by passing the crushed slag over it before shipment. To my great surprise we recovered three times the amount expected. This being a charcoal furnace the volume of slag was exceedingly small, about 400 or 500 lb. per ton of iron, or about half the slag volume in coke practice. Assuming that the coke slag contained as large a percentage of its own weight as the charcoal we should reasonably expect to recover almost 1 per cent of the total iron made by a coke furnace if we could treat this slag the same way. (Since the above was written I find that this percentage is actually being recovered at some coke furnaces.)

At plants where special efforts have been made to settle the slag before disposing of it very respectable tonnages of iron per month are recovered almost without expense. Mr. Reese has probably carried this work further than anyone else, and has recovered iron in this way amounting to hundreds of dollars a month per furnace. Where the slag is handled in hot pots a visit to the slag dump will almost always reveal a vast number of stringers of iron which had evidently settled to the bottom of the ladle during its journey to the dump, and run out underneath the cinder when the ladle was emptied. This is a matter which will undoubtedly receive increasing attention as time goes on.

As regards the iron chemically contained in the cinder the conditions are very different; this is commercially quite impossible of recovery. The amount varies

with the kind of iron produced and the furnace practice—it is in a general way proportional to the color of the slag.

A white slag probably contains one-tenth of 1 per cent of iron or under, while one which contains 1 per cent of iron is dark brown or black. The black slags made when a furnace is in trouble contain very much higher percentages than this. When a furnace is simply cold and making high sulphur iron, but still operating regularly, the percentage is likely to go up to 5 or 7, but when the furnace is in serious trouble, and the cinder too cold to be tapped in the regular way, it runs much higher than this in iron.

As a general thing conditions around the plant at such times are not conducive to scientific investigations of the slag, and not many have been made as far as my knowledge goes. But once or twice when a charcoal furnace under my management was in one of its periodical messes it produced a rather remarkable slag, and analysis of this showed about 25 per cent of iron, and as I recollect it about equal amounts of lime and silica. This slag was almost as fluid as water in spite of an exceedingly low temperature. No determination of the latter was made, but basing the estimate on its appearance as compared with that of many slags whose temperature was determined, I should think that it did not exceed 1800 deg. Fahr. This slag was very interesting from another point of view. In spite of its fluidity it was evidently immediately at the temperature of solidification, because while the stream of slag flowed rapidly on account of its fluidity it was instantly covered with a frozen crust as it came out of the furnace, the whole surface of the runner being covered solidly over with this dead-black crust, and a good-sized hand-ladle of the material, no matter how quickly it was dipped, was covered solidly with this black crust the instant it was dipped, though beneath it was full of this thin fluid slag at a red heat.

This, of course, does not bear on the question of the loss of iron in the slag in normal practice, since such conditions are about as far from normal as they can go without having the furnace absolutely frozen up. It is of interest, however, as showing that as the temperature drops the percentage of iron passing into the slag increases. In fact, all furnacemen who have brought a furnace through a serious "sickness" know that there are certain phases of furnace conditions in which the iron and slag do not separate, or only after a considerable interval of time, coming out of the furnace as a more or less homogeneous solution of one in the other.

In all matters concerning slags, and especially in trying to correlate with the results of practice scientific data based on the use of chemically pure ingredients, we must remember two vital facts: First, the oft reiterated difference between melting temperature and free-running temperature. Second, the important, and at times overwhelming, influence exerted by small quantities of foreign substances upon admixtures of chemically pure materials. All such substances mentioned earlier—magnesia, calcium sulphide, manganese and iron oxide, as well as the alkalies arising from the ash of the coke or occurring in the ore—have a marked tendency to produce silicates of lower melting temperature than those of lime and alumina, and we do not know what effect even small percentages of these materials may produce upon the melting point and free-running temperature of the actual furnace slags which always contain more or less of them.

At the present time it does not seem likely that we shall know anything about this until a great quantity of water has run under the bridges.

New York City.

Wood Flour

BY FREDERICK W. KRESSMANN

Chemist in Forest Products, Forest Products Laboratory,
Madison, Wis.

Wood flour is ground or milled wood that has been screened so as to remove coarse particles and also to give particles having some uniformity in size. Wood flour is usually sold as 40, 60 or 80 mesh,* although one large foreign purchaser has the following specification for dynamite flour:

20 per cent must pass through an 80-mesh screen
50 per cent must pass through a 60-mesh screen
100 per cent must pass through a 50-mesh screen

The different properties of a good wood flour are:

- 1st—It must be white
- 2nd—It must be light and fluffy
- 3rd—It must be absorptive

All industries in which wood flour is used (and these will be considered in greater detail later) require a white or very light cream colored flour, although absorptive qualities are demanded in a large degree only in dynamite flours. Color and weight considerations, therefore, limit the species of wood which may be used to the white, light non-resinous conifers and to the white broad-leaved woods like aspen and poplar. Spruce, white pine and poplar are the species most often used. The wood must be barked before grinding and round wood, slabs (barked) and sawdust free from bark may be used.

The grinding of the wood is performed in two distinct types of apparatus—either stone mills or steel burr roller mills. In Europe, particularly Scandinavia, where a great deal of wood flour is made, the stone mills seem to be used exclusively and most of the early plants in this country use this type of mill. The stones are from 40 to 60 in. in diameter and only the lower stone is driven, the upper one being stationary. The mills are driven with water power turbines, since flour produced with other sources of power cannot compete with Norwegian flour ground by water power.

The wood after barking is first reduced to chips by means of the usual type of chipper or hog. These chips along with a certain proportion of the screenings are fed to the mills which are completely inclosed (with the exception of an opening at the top) with an iron or steel cover. Sufficient steam or water is added to prevent firing and also to keep down the dust. The fine stuff from the mill is then drawn or blown through iron pipes or sheet metal ducts to the screening apparatus, which may be of several types, and which may be either bronze wire or silk bolting cloth, for both are used. After screening the flour is packed either in compressed bales (the imported material comes in this way) or else is sacked with automatic sacking and weighing machinery.

Mills of the above type require from 45 to 50 hp. per twenty-four hours per ton (from 1200 to as high as 1500 hp.-hr. per ton) of flour produced, the power requirement being about the same as in the production of mechanical ground wood pulp.

Another type of mill was developed on the Pacific Coast about twenty-five years ago and was designed especially to handle sawdust as a raw material. This grinder consists of a number of pairs of corrugated chilled steel rolls which turn toward each other. One of the rolls rotates three times as fast as the other, thereby actually cutting the sawdust which comes between them. The slower roll has its corrugations arranged so that they form pockets to hold the dust while the faster roll does the cutting. There are three stands or rolls, the corrugations being progressively finer on each stand.

*Screens of bronze wire having 40, 60 or 80 meshes per linear inch.

The sawdust is screened before reaching the first rolls so as to remove slivers, small blocks, etc. It is then passed over a strong electric magnet to pick out any particles of iron or steel present and is also screened through bolting cloth between each pair of rolls to remove material of suitable fineness. The production of wood flour from sawdust in this type of mill requires only from 20 to 25 per cent of the power required with the stone mills.

Before the war Norwegian wood flour was delivered at our Atlantic ports for from \$12.50 to \$15 per ton and domestic material sold in competition therewith. The domestic production is largely controlled by one concern, although mills are scattered all over the country from Maine to California wherever the combination of proper wood and water power is available.

Uses

The principal uses for wood flour are in the manufacture of dynamite, linoleum, artificial plastics and flooring, and as an inert absorbent in many industries.

DYNAMITE

Dynamite consists essentially of nitroglycerine absorbed in some porous material. For this purpose wood flour, wheat flour mill refuse, and infusorial earth (kieselguhr) are the principal materials used and wood flour is the one commonly used to-day. In addition, a certain amount of oxidizing material, either sodium or potassium nitrate with traces of calcium carbonate, magnesium carbonate, or zinc oxide are used. The latter materials are added to neutralize any free acid that may be formed by the decomposition of the nitroglycerine in long storage.

The composition of typical dynamites is as follows:*

Moisture	..	1.4
Nitroglycerine	40	60.6
Sodium or potassium nitrate	44	18.6
Wood flour	15	18.2
Calcium carbonate	1	1.2

A dynamite flour must be both white and highly absorptive. Since dynamite darkens with age a light-colored stick is indicative of fresh stock and trade demands, therefore, require the use of a white flour. For this reason it would be practically impossible to introduce the use of a wood flour produced from any colored woods. A good flour should be capable of making a 60 or 70 per cent dynamite (60 or 70 per cent of the total weight being nitroglycerine) without permitting leakage or exudation of nitroglycerine.** It is possible to improve the absorptive qualities and power of a flour by mixing it with water, boiling it actively for a short time and then drying, although this process, of course, increases the cost of production appreciably. For dynamite purposes, therefore, wood flour must be as white as possible, it must be absorptive and must be of the proper weight not only because the size of stick and number of sticks per box is standard, but also because too much flour cannot be used because it would disturb the carbon and oxygen balance in the explosive.

In 1900 over 85,846,000 lb. of dynamite were produced in the United States, containing over 9,934,000 lb. of wood flour. In 1909 the production of dynamite increased to about 195,156,000 lb., although the amount of wood flour used in this dynamite was not stated. The proportion of wood flour used in dynamite in 1909 was probably greater than in 1900 because of a tendency to produce dynamites of greater strength and the gradual replacement of other absorbents with wood flour. The 1909 consumption of wood flour for dynamite was probably around 20,000,000 lb. Since 1909

the production of dynamite has no doubt continued to expand and develop as before.

LINOLEUM

In the manufacture of linoleum, wood flour is used exclusively in the production of goods belonging to the inlaid class, either "granulated inlaid" or "straight-line." Cork linoleum is always dark, either the natural brown, or dark red or green. Patterns are printed on cork linoleum, but the pattern soon wears off, leaving the dark base. For the production of inlaid goods in which the pattern goes clear though the piece to the burlap backing a white base is naturally necessary, not only to furnish a white background where desired but also to permit of dyeing to any color. For this reason a flour as white as possible is desirable.

Linoleum consists of wood flour or cork flour mixed with a cementing material which is spread out on burlap and rolled or pressed hydraulically thereon. The cement consists of oxidized linseed oil melted with rosin and Kauri gum. The cement is the expensive constituent, it being worth from \$125 to \$175 per ton, depending on the price of linseed oil. Naturally the lightest flour will produce the largest volume of goods, since the raw materials of linoleum are purchased on a weight basis and sold on a volume basis. The weight per cubic foot is, therefore, along with the color, of prime consideration to the linoleum manufacturer.

The following table shows the comparative weights per cubic foot of cork and wood flours of different sizes:

28-mesh cork	.....	6.25 lb. per cubic foot
56-mesh cork	.....	7.50 lb. per cubic foot
80-mesh wood, imported	.....	13.0 lb. per cubic foot
40-mesh wood, domestic	.....	9.0 lb. per cubic foot

Another manufacturer reports as follows:

26-mesh cork	.....	4 to 4.5 lb. per cubic foot
60 to 80-mesh wood, imported	.....	4.8 lb. per cubic foot
60 to 80-mesh wood, domestic	.....	6.8 lb. per cubic foot

The difference in the above figures is due chiefly to the method of measuring and the amount of tamping in the measure, but in either case the wood flour weighs about 50 per cent to 100 per cent more than the cork. Cork waste before the war was worth about \$35 per ton and it costs about \$5 per ton to grind it with power at 1½ cents per kilowatt. Practically all cork flour used in this country is ground here either from domestic waste or waste from Spanish cork mills. Cork flour is, therefore, worth about three times as much as wood flour, but since they both require equal amounts by weight of cement and since the latter is the expensive item and also because the volume of goods produced from cork is so much greater than that from wood, the cork linoleum is cheaper for goods of equal thickness than wood flour linoleum. Cork linoleum is also cheaper to manufacture than wood linoleum because it is simply rolled between calender rolls, whereas the production of inlaid linoleum requires a considerable amount of handwork in the production of granulated inlaid and also a tremendous expense for dies in the production of "straight line." The seasoning time for cork is also less than wood flour linoleum of equal thickness. Cork linoleum is slightly more elastic than wood flour linoleum, although wearing qualities are about the same.

Here also the importance of a white flour with a low weight per cubic foot (fluffiness) is noted.

In 1909 about 4,460,000 sq. yd. of different kinds and thicknesses of inlaid linoleum were produced in this country. No statistics are available in which this production is classified into different thicknesses and grades. In general, however, the grades most commonly used will weigh from 8 to 12 lb. per square yard (exclusive of the weight of the paint backing) and will contain from 40 to 50 per cent of wood flour.

*Bureau of Mines Bulletin No. 51, "The Analysis of Black Powder Dynamite," by W. O. Snelling and C. G. Storm.

**For pressure and centrifugal tests see page 9, Bulletin 51, Bureau of Mines.

MINOR USES

For composition flooring, plastics, oatmeal paper, etc., the principal requirement is light color, although in some cases certain species are necessary as in the production of artificial bates for tanneries. The latter consists of a mixture of wood flour, ammonium chloride and certain animal extracts which are absorbed by the wood flour. Here again the trade demands a light colored product and it has been found that flour from broad-leaved woods like poplar will cause a discoloration on storage so that only flour from spruce or white pine may be used.

U. S. Department of Agriculture, Forest Service,
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Antimony Production in Hunan Province, South China

It is well known that China has for many years held the position of the world's largest producer of antimony. In view of the shortage of antimony in this country and the present attempts to smelt antimony ore here, the following excerpt from an article by A. S. Wheler in the *Bulletin of the Institution of Mining and Metallurgy* (London), Feb. 17, 1916, should prove interesting.

The province of Hunan, in South China, is the chief source of the Chinese supply. The chief mine is the Hsi-Keng-shan field, and is generally referred to as the Sinhua mines. The ore is stibnite Sb_2S_3 oxidized in places to cervantite. It is of remarkable purity, carrying a fraction of a per cent of arsenic and traces of lead and copper. The entire field is in the hands of Chinese.

The ore is rough-sorted underground and carried to surface in basket loads of 60 catties (79 lb.) weight or more. It is then cobbled or close-cored. The picked ore averages about 60 per cent Sb; the balance, together with the fines and mine sweepings, is reduced by hand to a size corresponding to $\frac{1}{4}$ -in. or $\frac{1}{8}$ -in. mesh, and is subjected to repeated concentrations by hand-jigging in shallow circular baskets immersed in water. The men who do this work become extremely expert and rapid at it; with a few half turns and a back shake or two they bring the waste to the top, skim it off, and repeat the process until the material has been concentrated to about 45 per cent metal.

Owing to the boom in antimony the waste heaps and dumps are being minutely gone over and their contents graded up by cobbing and concentration, this work being usually left to the "small workers," or poorer people, who sell the product to the mine owner at 2000 to 3000 cash per picul.

There are seven local smelting works, two of which are privately owned, the balance being customs works.

These are all turning out crude only, with the exception of the Mei-hsiang Company, which also started to produce regulus by smelting the oxide ore in reverberatory furnaces. Their total output had only amounted to about 100 tons, when the Hua Chang Smelting Co. of Changsha, who held the monopoly in China for the production of regulus, and also have powerful friends at Court, successfully protested, however, against what they regarded as an infringement of their rights by the Mei-hsiang Co., with the result that the latter concern was recently absorbed by them. This monopoly, it should be mentioned, has since been considerably curtailed, and is now in force only within 100 li of Changsha city.

The smelters make an all-round returning charge of 15 strings (16s. 3d.) per ton of crude produced, and will not accept ore below 40 per cent grade; this,

however, is estimated solely by its appearance. The ash is the smelters' perquisite, and the local coal costs 5 strings (5s. 5d.) per ton delivered. A description of this process, which is the same throughout the province, is given later under the heading of smelting.

The output of crude from this field is placed at rather over 1000 tons per month, but in addition to this a few hundred tons of high grade ore are shipped to Changsha for treatment or export.

Next in importance, but coming a poor second, are the Panshi mines, the output of which (about 400 tons of 30 per cent Sb grade) goes to the Hua Chang Co.'s works at Changsha where it supplies the Herrenschmidt furnace mentioned later, employed in the production of regulus.

There are numerous other smaller producers and the stimulus given to antimony mining by the rise in price has resulted in the profitable working of many small mines, which under normal conditions are unrenumerative. A few thousand tons of high-grade ore, and a small quantity of "ash" or liquation residues, are exported annually, but the bulk of the production is marketed in the form of "crude" and "regulus." These two terms are misnomers sanctified by long usage; the term "antimony crude" being applied to the product obtained from liquation of the sulphide, stibnite, and "regulus" meaning the metal, sometimes inaccurately styled, "refined antimony."

The type of furnace employed by the Chinese for the production of crude is the same throughout the province. It consists as shown in Fig. 1, of a narrow furnace built of ordinary brick and containing two pairs of pots or crucibles. The upper one of each set, into which the ore is charged, is fitted into the lower as shown, and the molten sulphide trickles through a $\frac{1}{2}$ in. hole in the bottom edge of the upper pot into the lower one which is bedded in the sand or ashes in order to avoid the full temperature of the furnace. A flue along the top of the furnace connects with the main flue or chimney about which the furnaces are invariably built in pairs, though it will be observed that each pair of crucibles is fired independently, being separated from its neighbor by a partition wall.

A moderate draught ensures the red heat necessary to effect fusion, and when sufficient of the liquated sulphide has accumulated in the lower vessel it is ladled out into moulds and solidifies into ingots of about 16 lb. weight each. These, when fractured, show a well-marked and characteristic acicular crystallization at right angles to the cooling surface.

The ingots are packed for shipment in wooden boxes containing 224 lb. net, and of 240 lb. gross weight.

The furnace is simple in design and cheap to build, and does not require much skill or experience to operate; one man usually attends four furnaces per 8-hour shift, for which he is paid 8 to 10 strings (say, 10s.) per month, in addition to his food.

The disadvantages of intermittent working and inefficiency do not appear to outweigh the good points in Chinese eyes, and no effort is made to check the continuous escape of fume which is so evident.

The pots used are usually of local manufacture, and have a life of 10 to 15 days; they contain a charge of 45 to 60 catties of ore, which takes from 2 to 4 hours to run down; it is not found that fines and dust in the charge cause any trouble.

The local method of estimating the content of an ore is by the number of units (tenths) of crude produced per picul, disregarding volatilization and residue losses. Thus a parcel of ore is tested by putting

a sample of one picul weight through the furnace just described and weighing the resultant crude. No allowance is made for residue of volatilization losses, the ash and flue dust being the perquisite of the smelter; hence it can be readily understood that there is ample scope for dishonest practice.

It is found that a high-grade ore, assaying 60 per cent Sb, yields about 70 per cent crude by this process, corresponding to an actual extraction of 83 per cent; whilst an ore containing 45 per cent Sb yields only 40 per cent crude, equivalent to a 64 per cent extraction.

The difference is mainly accounted for in the ash or residue, which rarely contains less than $12\frac{1}{2}$ per cent, and may exceed 30 per cent Sb; this is used in the manufacture of regulus. The balance is made up by volatilization, and may be reckoned at 3 per cent to 5 per cent of the original Sb_2S_3 content; this is partly recovered in the form of flue dust.

Crude varies from 68 per cent to 78 per cent Sb

cating with an exhaust fan, which blows into a scrubber or coke-tower sprayed with water.

The essential feature of the process lies in the regulation of the admission of air, whereby the ore is subjected to a volatilizing roast, producing Sb_2O_3 , which is immediately drawn off and condenses in the form of a pink-colored powder.

It is removed from the chambers through handholes, and is then smelted in reverberatory furnaces with coal, charcoal or coke, and soda ash, the latter serving as a protective covering and reducing any Sb_2S_3 present. There is, however, a considerable loss by volatilization of the Sb_2S_3 , which is partly recovered as flue dust; the total loss may exceed 30 per cent of the original Sb content of the ore or ash.

The oxide ores, which range in metal content from 40 per cent to 80 per cent are smelted direct in reverberatory furnaces. The Mei-hsiang Company at Sin-hua stated they were smelting a 45 per cent oxide ore, using as flux 14 lb. powdered coal and 5 lb. soda

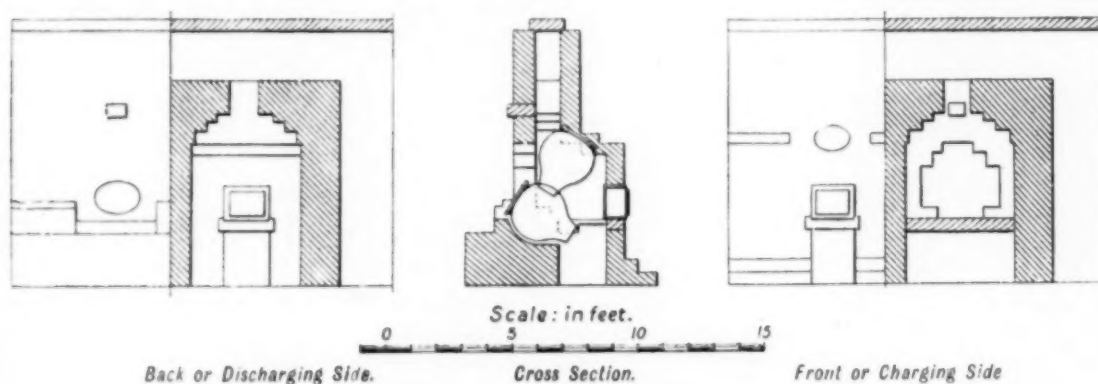


FIG. 1—ANTIMONY CRUDE LIQUATION FURNACE

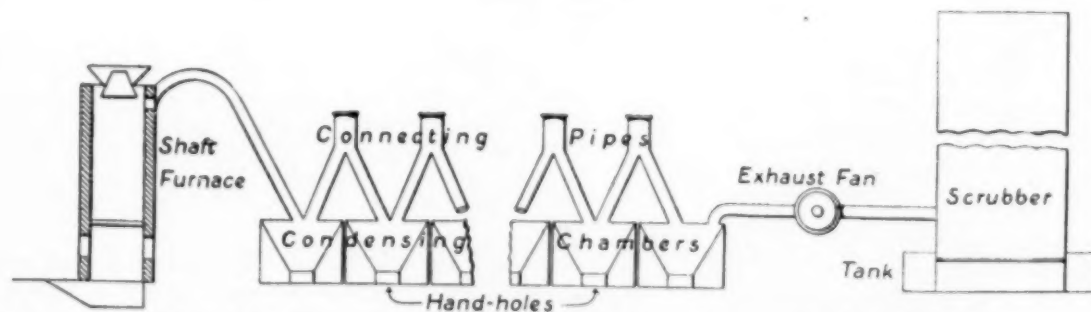


FIG. 2—DIAGRAM OF HERRENSCHMIDT FURNACE (NOT DRAWN TO SCALE)

and is sold as 70 per cent standard which corresponds to 98 per cent Sb_2S_3 .

Regulus is produced principally from the lower-grade ores, containing about 30 per cent Sb, and from liquation residues, and to a less extent from the oxidized ore, cervantite, which contains 79 per cent Sb when pure.

The Hua Chang Company who, as previously mentioned, hold a monopoly for the production of regulus within a radius of 100 li (36 miles) of Changsha city, also own the patent rights for China of the Herrenschildt furnace. This appliance (See Fig. 2) consists of a shaft furnace into which the ash or ore previously broken small by hand and mixed with 10 per cent of coal, coke or charcoal is charged. Leading from the furnace is a line of condensing chambers connected with each other by cast iron pipes of ample diameter (12 in. or more) passing from the top of one chamber with an inverted V bend into the top of the next chamber, and finally communi-

ating with an exhaust fan, which blows into a scrubber or coke-tower sprayed with water.

Some regulus furnaces have recently been built in Hankow in which air blast is supplied at the grate and the condensing chambers are water-cooled, but otherwise follow the lines of the Herrenschildt.

Analyses show Hua Chang regulus to contain from 98 per cent upwards of metal, with 0.15 per cent arsenic, and trace of lead, copper and zinc. Generally speaking, the purity of both the crude and the regulus is due to the remarkable freedom of the ores from associated deleterious minerals such as mispickel, galena, copper pyrites, and blende.

The American Society of Mechanical Engineers will hold its spring meeting at New Orleans from Tuesday, April 11, to Friday, April 14, inclusive.

Belgian Chemical Industries

The chemical industries of Belgium before and during the war which were more or less developed are discussed by Professor **H. Hubert**, of Liege University, in an article in *The Engineer* (London).

MINERAL ACIDS AND PHOSPHATES OF CALCIUM

Twenty-seven companies were engaged in the production of sulphuric acid. For a long time it was made only by the so-called chemical factories, established in the valley of the river Sambre and near Antwerp. But some years ago the manufacturers of zinc were obliged, in order to avoid troubles in the neighborhood and numerous complaints and suits, to abandon the simple roasting of their blende and to transform their sulphurous acid into sulphuric acid or to erect special works for this purpose. Of course, this transformation increased considerably the output of sulphuric acid, which now reaches 320,000 tons per annum. Thirteen works produced nitric acid, the greatest part of which is used in the manufacture of sulphuric acid, nitroglycerine, dynamite, and nitrocellulose for smokeless powder and artificial silk. The material used is the Chili nitrate of soda. A small quantity is used for the production of nitrates of ammonia. The total yearly output is over 11,000 tons. The production of hydrochloric acid by eleven works amounted to about 30,000 tons per year, and was regulated by the Co-operative Company Union Commerciale and partially exported to Germany and Holland. Superphosphate of lime was manufactured by thirty-three works, sixteen of which produced their own sulphuric acid. The total yearly output was about 350,000 tons, thanks to the importation of phosphates from the region of the river Somme in France and of Florida in the United States. Half the production of superphosphate was exported to France, Spain, Holland, and to the Baltic harbors. The steel works, which use the Thomas and Gilchrist process, produce yearly about 225,000 tons of phosphatic basic slag, which is treated in five of these works and in six other shops.

POTASSIC, SODIC, AMMONIC, AND CALCIC SALTS

The principal product in this class is the carbonate of sodium, or soda, which was formerly manufactured by means of the Leblanc process—reaction of carbon on chloride of sodium to produce sulphide of sodium, and decomposition of this latter by carbonate of calcium, which forms carbonate of sodium and sulphide of calcium. In 1838 two Englishmen, Dyar and Hemming, patented a new process, in which chloride of sodium is treated by carbonate of ammonium and gives bicarbonate of sodium. This latter is transformed into carbonate by roasting. They did not succeed industrially, and other Englishmen, like Muspratt in 1840, Gossage and Deacon, and the German Kunheim in Berlin, were not more happy. In 1863 the famous scientist and philosopher, Ernest Solvay, in his turn tried this process and erected in Couillet, near Charleroi, works which were the starting point of the great soda industry. Some time later M. Solvay founded the Dombasle Works, near Nancy, and granted a license to Messrs. Brunner, Mond & Co., Northwich. These two works are still the most important in the world, producing yearly one 150,000 and the other 200,000 tons. Later, M. Solvay established in 1883 the Bernsburg Works in Germany and the Beresnicki Works in Russia; in 1884 the big Syracuse Works in the United States and the Ebensee Works in Austria, etc. The Couillet Works are still in activity, and produce yearly about 25,000 tons. Carbonate of ammonia was first produced only by gas works. The need of large quantities of this matter induced numerous collieries to build recovery coke ovens, some of which

were erected by Messrs. Solvay at their own cost, the collieries agreeing to give them the by-products while reserving their coke.

VARIOUS INORGANIC CHEMICAL PRODUCTS

The Overpelt Works, in Limburg, the principal production of which is zinc and lead, manufactured also sulphate of copper, arsenious acid, oxide of nickel, and of cobalt. The Vieille Montagne Company produced also more than 6000 tons of oxide of zinc, or *blanc de zinc*.

EXPLOSIVES

The continuous development of mines and quarries in Belgium required, of course, the production of a large quantity of explosives, and led to the establishment of an important industry which was not only able to meet the whole national needs, but to supply several countries in Europe and in other parts of the world. Fifty works manufacture the different explosive products, the total output of which may be rated at 4000 tons and estimated at £300,000, in value, the third of which is exported. The smokeless powders, the basis of which is nitrocellulose, are manufactured in the two principal works of Belgium—500 tons. The manufacture of matches, which may be connected with the explosive industry, is concentrated in East Flanders. Nine works manufacture wooden and two wax matches, to a total value of nearly £175,000 per year. Sweden and Germany import yearly matches worth about £14,000, but this importation is decreasing, while the Belgian exports reach more than £100,000, specially to England, her Colonies, and the Mediterranean countries.

THE MANUFACTURE OF ARTIFICIAL PORTLAND CEMENT

This began in Belgium about forty years ago, and developed rapidly on account of the important need for buildings and engineering construction, and of the facility of obtaining the ingredients. This development led to the erection of numerous and large works in the provinces of Liège, Namur, Hainaut, Brabant, and Antwerp, which had an output of about a million tons, largely surpassing the national needs, half of which was exported to England and her colonies, to the United States, and South America. Several metallurgical companies—for example the John Cockerill Company—manufacture a special cement by mixing their blast-furnace slags with lime, hard bricks being also made from slags.

Electric Steel Furnaces In England

In London *Electrical Engineering* of March 2 a review is given of the present position of the electric steel furnace in Sheffield. It is pointed out that the war has been a means of bringing the quality of the electric furnace for steel refining well to the front.

Three types of electric steel furnaces are in use in Sheffield, and "it is satisfactory to learn that all three types give excellent results. The Heroult type of furnace is much in evidence, the company having at their disposal a large amount of actual practical experience. The type of furnace manufactured by Electro-Metals, Ltd., has also found favor, while there is one example of the Rennerfelt furnace in regular operation."

The general practice of steel refining is the same as in this country. Two slags are used; by the first a phosphorus is removed, by the second sulphur. The article concludes: "The trend of events at present seems to indicate a very important future for the electric steel furnace; it is fortunate that in Sheffield this is well catered for by the energetic and up-to-date policy pursued by the Corporation Electricity Department." Thus it seems that the electric steel furnaces are supplied with power from the central station supply system.

The Available Hearth Heat of the Blast Furnace

BY ALEX. L. FIELD

It is in no spirit of criticism that the author approaches the fundamental hypothesis of the series of articles by J. E. Johnson, Jr.,¹ which have recently appeared in this journal. No furnace man can consistently deny that Mr. Johnson's new hearth heat balance answers numerous problems which baffled the old style "heat balance" of Bell and his co-workers. What I would impress upon the reader at the outset is that the present article should be considered in the light of an interpretation, from the viewpoint of the physical chemist, of the important work of Johnson in having solved, more completely than had been before accomplished, some of those perplexing operating problems which confront the works superintendent at every turn.

However much I would emphasize the value of the hearth heat balance, I wish to state that Mr. Johnson seems to have regarded the fundamental laws which form the basis of his theory from the standpoint of the engineer rather than that of the physical chemist.

The "hearth heat" theory undoubtedly agrees well with the results obtained in practice. It should certainly do so, because it is essentially the logical method. However, in spite of the fact that the idea behind the theory which has been presented in the series of articles above mentioned is the correct one, the method of interpreting and of establishing this theory seems unfortunate.

In the opening instalment of the series² it is stated in effect that the blast furnace depends upon a law, similar to the second law of thermodynamics, in addition to the first law, which forms the basis of the heat balance of Sir Lothian Bell. As we shall see later, Mr. Johnson, throughout his series of articles, has made use only of the first law of thermodynamics—i.e., the law of the conservation of energy. In fact, the fundamental principle upon which it is possible to derive Mr. Johnson's data is none other than Hess' law of constant heat summation, which was promulgated even before the doctrine of the conservation of energy was firmly

established. The expression, $\frac{T_1 - T_2}{T_1} \times Q = Q_h$, derived

by Johnson³ (T_1 being the theoretical combustion temperature, T_2 the critical temperature, Q the total heat, and Q_h the hearth heat) and attributed by him to the second law of thermodynamics has no direct connection with the second law, for the very obvious fact that it does not contain a single expression or term which represents the conversion of heat or chemical energy into either mechanical or electrical work. It represents in reality only a heat transfer, although it does bear a superficial resemblance to the expression for the maximum efficiency of a gas engine operating in a Carnot cycle. The conversion of chemical energy into work is expressed by the familiar free energy equation⁴ $A = RT \ln K$, which is based upon the second law of thermodynamics and the law of mass action. It is sometimes called the equation of the "reaction isotherm." However, neither this particular equation nor the general principles of the conversion of heat into work, or vice versa, is pertinent to the present discussion; nor does Mr. Johnson attempt to use the second law of thermodynamics.

The usual method of calculating the theoretical tem-

perature of combustion is essentially that of Johnson in calculating the critical temperature diagram⁵. With a critical temperature equal to the theoretical temperature of combustion the hearth heat is simply equal to zero.

In a nutshell, Mr. Johnson's "hearth heat" or "available hearth heat" at a "critical" temperature of 2750 deg. Fahr. is equal to the heat of the reaction, carbon + oxygen = carbon monoxide, at a temperature of 2750 deg. Fahr. minus the amount of heat necessary to raise the blast up to 2750 deg. Fahr. For the sake of brevity we will consider in the present article only the case of the dry blast. The simplified method of attacking the problem which will be presented should make it readily possible for the reader to extend it to the moist blast.

If we let Q_H equal the hearth heat, Q_T the heat of the reaction at a critical temperature T , and H_B the mean heat capacity of the air of the blast between the temperature T and the temperature of the blast T_B , we have, from the preceding paragraph,

$$Q_H = Q_T - H_B(T - T_B) \quad (1)$$

While the author does not intend to discuss in the present article the exact nature of the "critical temperature" nor what it really corresponds to, i.e., whether it is equal to the temperature of the freely flowing slag, the temperature at the tuyeres, or any other similar temperature—it seems to him desirable to establish according to well-known laws the equation which gives us the hearth heat at any particular critical temperature. It may be remarked here that Mr. Johnson's method of calculation ought to give comparable numerical results were there not a difference in the values used for the specific heat of carbon, which Mr. Johnson takes equal to about one-half the generally accepted value.⁶ He has consistently taken as the mean specific heat of carbon between 0 deg. Fahr. and 2750 deg. Fahr., the value 0.23, whereas, according to the data of Richards⁷ which he accepts and which we shall make use of entirely for the purpose of direct comparison, this value should be 0.43. The values for hearth heat obtained by Mr. Johnson while using the value 0.23 are much too low, the percentage error introduced being largest for high critical temperatures.

THE HEAT OF REACTION AND THE HEARTH HEAT AT ANY TEMPERATURE T .

As is well known, the heat of reaction varies with the temperature. The heat of reaction at any temperature T is defined as the quantity of heat evolved or absorbed when both initial and final products are at the temperature T . In general, thermochemical measurements are made at room temperature because it is convenient.

Consider now the two following processes⁸ to take place. First, allow a chemical reaction (in our case the combustion of carbon to carbon monoxide by oxygen) to occur at a temperature T ; heat the products of combustion to a slightly higher temperature $T + dT$. Secondly, heat the reacting substances from T to $T + dT$ and allow the reaction to occur at a temperature $T + dT$. According to the law of conservation of energy, the total heat evolved in the two processes must be equal. Let Q be the heat of reaction at the temperature T , and $Q + dQ$ the heat of reaction at the temperature $T + dT$. Then $Q - h'dT = Q + dQ - h dT$, where h and h' are the mean heat capacities of the reacting substances and the products respectively. Therefore,

$$\frac{dQ}{dT} = h - h' \quad (2)$$

¹J. E. Johnson, Jr., "Thermal Principles of the Blast Furnace," *Met. Chem. Eng.*, Vol. 13 (1915), pp. 718, 787, 833, 905 and 954.

²Op. cit., p. 718.

³Op. cit., 833.

⁴Walter Nernst, "Theoretical Chemistry," p. 644. 1914. Macmillan & Co.

⁵Op. cit., p. 720, Fig. I; also p. 789, Fig. I.

⁶Op. cit., p. 720.

⁷Op. cit., p. 791. Also, J. W. Richards, "Metallurgical Calculations," Vol. I, 1906.

⁸See Walter Nernst, "Chemistry and Thermodynamics," pp. 10-12. Chas. Scribners Sons, 1907.

Equation (2) shows that the increase in the heat of reaction per degree is equal to the difference between the mean heat capacities of the reacting substances and products of the reactions. This is none other than Hess' law. Therefore, if Q is known for any particular temperature and if the specific heats of the substances involved are known, together with their dependence on the temperature, it is possible to draw a curve showing

the relation between Q and T , while $\frac{dQ}{dT}$ in equation (2)

is the slope of the curve at any temperature T .

Integrating equation (2) we get

$$Q_T = Q_o + (h - h') T$$

or

$$Q_T = Q_o + hT - h'T = Q_o + h_c T + h_o T - h_{co} T \quad (3)$$

where

h_c = mean heat capacity of carbon between T_o and T ,

h_o = mean heat capacity of oxygen between T_o and T ,

h_{co} = mean heat capacity of carbon monoxide between T_o and T ,

and

Q_o = heat of reaction at T_o , where T_o is the arbitrarily chosen reference temperature, such as the freezing point.

Equation (3) gives Q_T , the heat of reaction at any temperature T , due to the combustion of carbon to carbon monoxide at the tuyeres. However, from this heat of combustion we must subtract the heat necessary to raise the blast up to the temperature T in order to get the amount of heat which is available. We will call this remaining heat Q_h , since it will be found to correspond to Johnson's hearth heat. Equation (1) gave us the relation $Q_h = Q_T - H_B(T - T_B)$. Now H_B is made of two parts, h_o and h_n , the mean heat capacities of the oxygen and nitrogen in the air of the blast respectively. Substituting $H_B = h_o + h_n$ in equation (1), we have

$$Q_h = Q_T + h_o T_B + h_n T_B - h_o T - h_n T \quad (4)$$

Substituting in equation (4) the value of Q_T from equation (3) and eliminating, we get

$$Q_h = Q_o + h_c T + H_B T_B - h_{co} T - h_n T \quad (5)$$

Equation (5) corresponds to Johnson's method⁹ of calculating Q_h , the hearth heat, for any critical temperature T . This method, as has been seen above, can be derived directly from equation (1), which is the expression we shall use in calculating Q_h , the hearth heat.

We see, therefore, that the hearth heat at any given critical temperature is equal to the heat of the reaction at that temperature minus the heat necessary to raise the blast up to the temperature T . For any given "critical" temperature T the hearth heat is a linear function of the blast temperature and has the general form $A + H_B T_B$, where A is a constant for any given critical temperature and equal to $Q_T - H_B T$.

When Q_h , the hearth heat, is equal to zero, then T , the critical temperature, is equal to the theoretical temperature of combustion for the given blast temperature. From Johnson's diagram¹⁰, we find by referring to the X-axis intercept (i.e., $Q_h = 0$), that, according to his calculations the theoretical temperature of combustion with cold (70 deg. Fahr.) blast is equal to 3090 deg. Fahr. According to the calculations which follow, this theoretical combustion temperature should be 3400 deg. Fahr.

Table 1 gives the values of Q_T , the heat of reaction at various critical temperatures. Table 2 gives the heat required to raise the blast from 32 deg. Fahr. to T deg. Fahr., where T is the critical temperature. By

means of these two tables it is possible to calculate the hearth heat Q_h for any given conditions by means of equation (1). The term $H_B(T - T_B)$ in this equation is gotten by subtracting from the heat required to raise the blast from 32 deg. Fahr. to T deg. Fahr., the heat required to raise the blast from 32 deg. Fahr. to T_B deg. Fahr., the temperature of the blast. Both of these last quantities are given in Table 2. In the tables, temperatures are given for convenience in both Fahrenheit and Centigrade degrees. All heat values, however, are expressed in B.t.u. per pound of fixed carbon burned in the hearth.

Fig. 1 shows graphically the value of the hearth heat for various critical temperatures and for dry blast at different temperatures. This revised diagram is similar to Johnson's diagram, except that the hearth heats are calculated for 1 lb. of fixed carbon burned instead of for 0.85 lb. For the sake of direct comparison, the hearth heat isotherms for blast temperatures of 70 deg. and 1400 deg. Fahr.—the two extreme cases considered—have been taken from Johnson's diagram, reduced to a common basis of 1 lb. fixed carbon, and plotted as dotted curves (see Fig. 1). The error introduced by using 0.23 as the mean specific heat of carbon between 0 deg. and 2750 deg. Fahr. is readily seen by comparing these dotted curves with the corresponding revised curves.

TABLE 1—HEAT OF REACTION

T		Heat of Reaction B.T.U. per Lb., Fixed Carbon
Critical Temperature Deg. Fahr.	Deg. C.	
2192	1200	4674
2372	1300	4707
2552	1400	4738
2732	1500	4772
2912	1600	4805
3092	1700	4835
3272	1800	4865
3452	1900	4897

TABLE 2—HEAT FOR RAISING BLAST TEMPERATURE

T		Heat Required to Raise Blast from 32 Deg. Fahr. to T Deg. Fahr. for 1 Lb. Fixed Carbon Burned
Deg. Fahr.	Deg. C.	
32	0	0
212	100	242
392	200	490
572	300	740
752	400	994
932	500	1242
1112	600	1501
1292	700	1764
1472	800	2016
1652	900	2284
1832	1000	2538
2012	1100	2812
2192	1200	3089
2372	1300	3346
2552	1400	3629
2732	1500	3915
2912	1600	4176
3092	1700	4468
3272	1800	4727
3452	1900	5027

One does not need to go far to find a simple explanation of why calculations based on the low hearth heat values of Mr. Johnson correspond as closely as they appear to do with the results of blast furnace practice. It is obviously because the fuel economy realized by a change of blast temperature, from 400 deg. to 1000 deg. Fahr., for instance, depends upon the difference between two hearth heat values. Now, although the error in the actual value of the two hearth heats may be considerable, the error in the difference of any two hearth heats is much smaller.

In regard to the way in which the available hearth heat is utilized, Johnson¹¹ says:

"It may be said without reservation that for every set of furnace conditions there is a certain critical temperature above which only certain necessary operations of the process can be carried out. It is not necessary to know what the operations are, and no attempt is made

⁹Op. cit., p. 720.

¹⁰Op. cit., p. 720; also p. 789.

¹¹Op. cit., p. 719

to enumerate them here, further than to say that they probably comprise the removal of the final traces of oxygen from the ore, the formation and subsequent superheating of the cinder, and the melting, carbonization, and superheating of the iron—"superheating" being used in the sense of heating above the point of fusion."

If the critical temperature is taken, as it is by Mr. Johnson, as the temperature of the freely flowing slag, it is impossible to explain how the heat required for the melting and superheating of the cinder above its melting point can be supplied above the critical temperature, which is higher than the melting temperature. Although we may assume, for instance, that on account of the physical state of the slag-forming materials in the smelting zone the materials must be heated as high as the critical temperature before slag formation is completed, it must be remembered that the slag thus formed at the critical temperature is already sufficiently superheated to flow freely and requires no heat above the critical temperature. It seems reasonable to assume that the formation temperature of the slag is no higher than its freely flowing temperature. If the formation temperature were higher than the critical temperature, the melted slag would be at a higher temperature than the critical temperature, which is contrary to the definition of "critical temperature." While, of course, the formation of the slag requires a considerable quantity of heat, this absorption of heat cannot lower the temperature of the slag, just as ice melting in a beaker of water, and thereby absorbing heat, cannot become colder than 0 deg. C. Such an absorption of heat must be isothermal.

The old-style heat balance of Bell fails because it considers the quantity of heat supplied to the furnace from the hearth to the top of the shaft—i.e., the heat supplied above the temperature of the top gases. Since

there is a continuous, though not necessarily uniform, temperature rise along the furnace axis from the top of the shaft to the zone of maximum temperature in the neighborhood of the tuyeres, and a much smaller drop in temperature along the furnace axis from the zone of maximum temperature to the hearth, there must be at least two zones at what we have been calling the "critical" temperature—one zone somewhat above the zone of maximum temperature and the other zone probably below the tuyeres. The "critical" temperature may possibly be so defined that the quantity of heat developed between the two zones above the critical temperature is more or less definitely related to the output of iron per pound of fixed carbon burned in the hearth. It is entirely possible, though not obviously necessary, that this critical temperature may correspond to the temperature of the freely flowing slag. Mr. Johnson's measurements and observations indicate that this relation is more or less approximately true. No one, of course, can expect to find an exact relation.

The hearth heat, i.e., the quantity of heat supplied above the critical temperature, includes (a) the heat lost by radiation and conduction between the upper and lower critical zones, and (b) the heat required for those final steps of reduction of ore and carburization of iron, and other similar adjustments in composition of molten iron, molten slag, and furnace gases, which occur between the critical zones.

Pittsburgh, Pa.

Some Sources of Error in the Iodometric Determination of Copper

BY CARL E. SMITH

To attain the greatest possible accuracy in rapid quantitative determinations of copper by means of the iodometric method, as often required in commercial analyses of metallic copper and its alloys, several factors must be considered that are frequently overlooked and in treatises dealing with technical analysis are either not emphasized enough or completely ignored.

Sampling

For instance, it is usually recommended in standard manuals to weigh out for the analysis such small quantities of metals as 0.5 gram, or even less. Unless the sample is in a very finely divided condition, which is usually not the case, and well mixed or for other reasons is known to be of uniform composition throughout, it is obviously impossible to obtain by means of such small quantities an accurately representative part of the entire sample. There have doubtless been many instances where results of analyses of parts of the same sample, made by different analysts or even by the same analyst, have differed widely for this reason alone.

Drillings and cuttings of copper products, as submitted for analysis, are often expected to represent the average composition of large lots of material, portions of which may differ considerably in copper contents. There is often so much uncertainty about the accuracy of sampling large lots of materials, even under the most favorable circumstances, that it is all the more necessary that the chemist should not add to a possible error in the original sampling a defective sampling of his own. Even when the sample is in relatively small pieces, the writer has often found it necessary to take 5 grams or more to avoid an error of that kind. When the pieces are large the best way, doubtless, is to cut up the entire sample into small fragments and weigh out a quantity large enough to leave no reasonable doubt that a thoroughly representative portion of the entire sample has been taken.

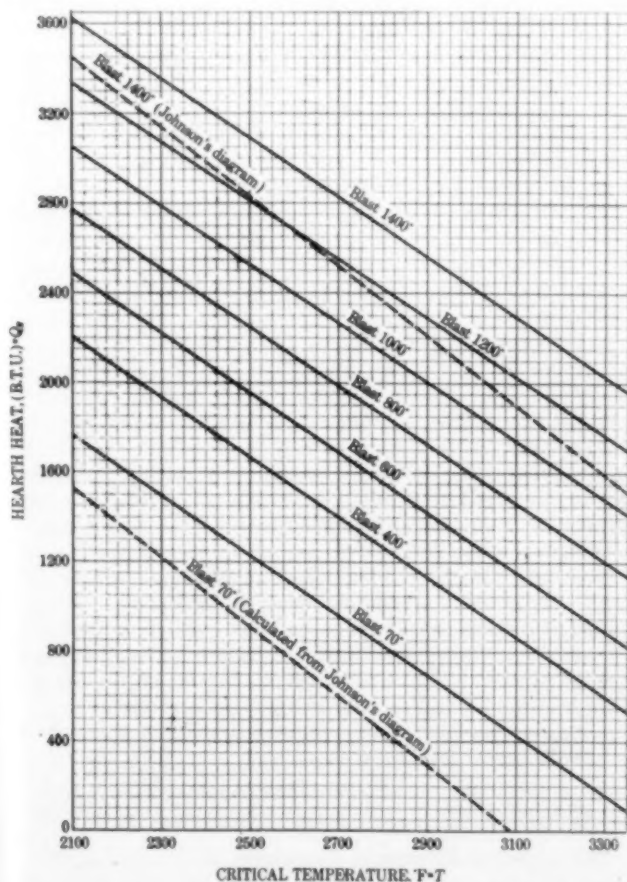


FIG. 1—REVISED HEARTH HEAT DIAGRAM BASED ON 1-LB. FIXED CARBON ACTUALLY BURNED IN HEARTH

As regards the sampling of large quantities of copper, a repetition of the excellent recommendations of the American Society for Testing Materials, made in its Year Book for 1915, may be of interest. For wire bars, cakes, slabs, billets, ingots and ingot bars of Lake and electrolytic copper, in connection with investigations of claims as to metal contents, they are essentially as follows:

"* * * Each party shall select a sample of two pieces. These shall be drilled in the presence of both parties, several holes approximately $\frac{1}{2}$ in. in diameter being drilled completely through each piece; scale from set shall be rejected. No lubricant shall be used and drilling shall not be forced sufficiently to cause oxidation of chips. These resulting samples shall be cut up, mixed and separated into three parts, each of which shall be placed in a sealed package, one for each party and one for the umpire, if necessary. * * *

For sampling copper ingots a Committee on Standard Methods of Analysis, of the American Chemical Society,¹ recommends as follows:

"Select six ingots at random from the lot. Considering three ingots as a rectangular unit, drill one hole in each ingot, one at the center and one at each end of a diagonal of the rectangle. Drill each hole entirely through the ingot, starting from the bottom. Start the drill on the surface sufficiently to remove the oxide before commencing to collect the drillings for the sample. Run the drill so as to prevent oxidation of the chips. Discard all drillings carrying oxide from the 'set,' or burned by the drill. Use no lubricant on the drill, and, if the sample shows oil or grease, remove this with ether. Sift all drillings on a screen with 250 meshes to the square centimeter, in order to remove material which is ground between the drill and sides of the hole. Extract with a strong magnet any iron which may have come from the drill. Keep the drillings in airtight bottles."

Errors in Analytical Procedure

A source of appreciable error may be in the method of dissolving the metal and in the preparation of the solution for titration. One may easily underestimate the loss incurred through a brisk effervescence while the metal is being dissolved in acid, even when the container is covered. For the same reason boiling should be avoided during the removal of the lower oxides of nitrogen, or at any stage of the analysis, for that matter. This is mentioned here particularly because several eminent authorities direct boiling at two or three stages of the operation. While this somewhat lessens the time required to complete the assay, it does so only at the expense of accuracy.

Neither is it necessary or advisable to add bromine, hypochlorite or other agent to convert lower oxides into nitric acid. Indeed, it is the writer's experience that introduction of halogen may be a positive source of error when the copper contains silver, which is often the case. The precipitate of silver halide is gradually decomposed by the nitric acid during subsequent heating, notwithstanding the statements in text-books to the contrary. This decomposition proceeds until the precipitate is dissolved, slowly generating lower oxides of nitrogen and bromine or chlorine. This disturbing factor needs no further comment. In the writer's experience there is no difficulty in completely expelling lower oxides within a reasonable length of time simply by heating the solution below a boiling temperature. That means has been used in this laboratory continually for a number of months with uniformly satisfactory results.

¹The Journal of Industrial and Engineering Chemistry, 1915, v. 7, p. 546.

Some other sources of error will be touched upon below.

Details of Procedure Recommended

For metallic copper the writer proposes the following procedure on the basis of assays by it of some hundreds of commercial samples:

Prepare the sample as recommended above. To about 6 grams, weighed to 0.5 mg., and contained in 200 cc. conical flask, add 20 cc. of water, then, through a funnel, which forms a baffle to the spray of liquid produced by the effervescence, small successive portions of strong nitric acid, 20 cc. in all, slowly enough to prevent a brisk reaction. When all the acid has been added and the reaction becomes too slow, warm on a hot plate and when solution is complete, remove the funnel and wash copper nitrate adhering to it into the flask with a little water.

Continue heating just below a boiling temperature until the vapors at the mouth of the flask are free from the characteristic odor of the lower oxides of nitrogen, and continue heating for at least 10 min. longer at the same temperature, to make sure that all traces have been expelled. There is no objection to heating considerably longer, provided no basic salt is formed.

Cool the solution and dilute it to 1 liter in a measuring flask. Pipette 50 cc. into a vessel suitable for titration. Add enough ammonia water to produce a permanent turbidity (4 to 5 drops), then 5 cc. of glacial acetic acid. Dissolve in the solution 3 grams of potassium iodide. (It is not advisable to keep a stock solution of the salt for this purpose, as sometimes recommended, since the solution on standing absorbs oxygen and develops iodate.)

Immediately titrate with 0.1 normal thiosulphate, with constant agitation of the liquid. When most of the iodine is decolorized, add starch solution and complete the titration by adding the thiosulphate very slowly toward the end, which aids in obtaining a sharp end point. A still sharper end reaction is obtained by running in a slight excess of thiosulphate, and titrating the excess with iodine. Of thiosulphate of about 0.1 normal strength 46 to 47 cc. will be required.

In accordance with the observations of Treadwell, it is best to let the thiosulphate solution stand for several weeks before determining its copper value, as it will then retain the same strength for some months, although it changes rapidly during the first few days after it is made.

A standard copper solution for determining the copper value of the thiosulphate, made from copper of known purity, should be prepared in exactly the same way as the solution of the copper to be assayed and the identical measuring flasks, pipettes and burettes should be used for both standardization and assay. It need hardly be mentioned that burettes of small bore and graduated for close reading are absolutely necessary for exact work.

It should also be obvious that suitable correction for variation in volume of the standard solutions, due to temperature changes, cannot be neglected if accuracy is desired. A difference of 5 deg. C. from the temperature at the time of standardization, for example, would otherwise cause an error of nearly 0.1 per cent.

An assay made in the manner described can easily be completed in less than two hours.

Carl E. Smith Testing and Research Laboratory,
New York City.

The General Chemical Company will erect a clubhouse for its employees at Pulaski, Va., the contract having been let for same.

The Metallurgical Disposal of Flotation Concentrates

BY R. J. ANDERSON

The flotation process has revolutionized the metallurgy of the base metals, particularly copper, lead and zinc, and from recent commercial practice bodes to extend its application to such an extent so as to replace the cyanide process at least in part, if not in whole, in some places. Oil flotation has had a radical influence on both mill design and on smelting operations, particularly copper practice, and the successful disposal of flotation concentrates is an important phase of the new metallurgy. This disposal involves the problems which deal with the handling of concentrates as produced by the different flotation processes and the subsequent smelting of the concentrates. This, then, gives rise to two divisions of the subject; namely, (1) handling of concentrates and (2) smelting of concentrates.

The Handling of Concentrates

Froth Breaking.—Flotation concentrates, *i.e.*, the froth entangling the valuable sulphides (and gangue in subordinate amount) plus water, is an unsmeltable product as such. The first step in the disposal operations requires a breaking of the froth, particularly if it be a mechanical froth, such as is produced by the Minerals Separation, Hebbard-Harvey, Janney or similar mechanically agitated machines. The pneumatic froth of Callow or Towne-Flynn is ephemeral and breaks of itself when removed from the influence of the injected air (although, of course, its stability is influenced by the kind of oil used), and is, therefore, more easily handled. The mechanical froth, however, is thick and more or less permanent, and its disposal has presented serious difficulties.

A common practice for froth breaking, which is quite effective, simply calls for the spraying of water on the froth as it flows in its launder. In a number of instances bucket elevators have proved quite efficacious; the splashing and striking of the buckets causes the froth to break up. At the Herculaneum plant of the St. Joseph Lead Company there have been installed pug-mills for this purpose. In addition, these mills insure a steady stream of concentrate feed to the mixing belt whereby the flotation product is mixed uniformly with the usual feed for the Dwight and Lloyd sintering machines. The method of running the concentrate over tables of the Wilfley or Card type has been tried and is successful in breaking up the froth. Froth may also be effectively broken by the addition of reagents such as acid or lime, or even by adding more oil. In regard to this latter, if an excess of oil is added to a successfully operating flotation unit the froth may be practically "killed." A filter of the pressure type, such as the Kelly, Shriver or other, will break up the froth in the dewatering operation.

Dewatering.—All flotation processes produce a wet, sloppy, frothy concentrate which is extremely difficult to handle and ship unless dewatered. The skillful and economical disposal of flotation concentrates preparatory to shipment and smelting is, therefore, an important problem. In discussing dewatering practice, certain machines have found their way into the mills and certain methods have been adopted which probably embody the tendencies toward a future standard practice. Some of the apparatus used for dewatering includes the following; *viz.*, settling bins, filters—pressure or vacuum, drag-classifiers, screw-classifiers and thickeners.

The practice of settling the froth in bins, while a common one, does not reduce the moisture sufficiently low for shipment by rail unless for short distances. The

mill of the Utah Leasing Company at Newhouse, Utah, has large bins of 200-ton capacity for settling the concentrates. Practically all of the larger plants have come to the use of filters either of the pressure or vacuum type, or both.

The functional utility of the filter lies in its ability to reduce the moisture content of the material treated to practically any desired percentage. Pressure filters of the Kelly type can take the flotation froth direct and perform the function of froth breaking and dewatering in the same operation. The pressure filter is more bothersome to operate, because it is intermittent in action and requires constant attendance. Although the pressure filter can reduce the moisture content to as low as 6 per cent, the vacuum type finds more favor. The vacuum filter is represented by the so-called Oliver and Portland types. This type of filter is not well adapted to the immediate dewatering of froth concentrates because such product will not cake well on account of its high percentage of moisture—60 to 70 per cent and occasionally considerably more. The pulp feed for vacuum filters should have a ratio of 1 to 1. If the froth be first broken and then dewatered in a Dorr tank, the vacuum filter can be used, and it is preferable to the pressure type by reason of its continuous operation and low operating cost. The vacuum filter in practice can make concentrates of any moisture content to as low as 8 to 10 per cent. Where concentrates are to be briquetted, such a low percentage of moisture is not necessary, but should be as high as 15 per cent. or more.

An example cited recently in the current technical literature, which gives a method of dewatering flotation concentrates, is the practice at the Inspiration mill in Arizona. Here the concentrates from the flotation processes and from the tables converge to a drag-classifier; the coarse product from this machine is sent to an Oliver filter and the fine product to a V-shaped settling tank, where it is thickened. The thickened and settled fine from the tank then goes to the filter. The filter cake from the Oliver machine is trammed to a bin and thence loaded into bottom-discharge railroad cars for shipment to the smelter. At the Miami mill in Arizona, the flotation concentrate is thickened in Dorr tanks and the thickened product then conveyed by bucket elevators to a group of 12-ft. x 12-ft. Oliver filters. The caked concentrate is scraped off over a steam-heated plate and then removed to a steel storage tank preparatory to shipment to the smelter.

A type of machine brought out in recent years by one of the Western companies which is applicable to the dewatering of flotation concentrates is the so-called Ovoca classifier. This is a classifier of the screw type. The froth is broken down effectively, giving a continuous clear overflow solution at the weir and a continuous discharge of dewatered concentrate—moisture 15-25 per cent. A screw dewaterer is in operation at the Oneida Stag mill at Idaho Springs, Col. At this place the flotation concentrates plus the table concentrates are passed through a screw dewaterer and the two are thus mixed and dewatered in one joint operation. The dewatering machine removes from 60 to 70 per cent of the slimes with the coarser table product, and the overflow removes the balance of the slimes. This latter goes to settling boxes and is there settled and thickened.

The practice of washing flotation concentrate is a development as yet new in American practice. The leading consideration in washing is the removal of part of the insoluble matter whose presence in the final concentrate detracts from its grade. Washing is employed at a New South Wales mill in Australia. Here the flotation product is led into settling bins and washed by means of spray water playing on it as it enters. The effect of this is to disintegrate the froth so that the

sulphides sink to the bottom and at the same time part of the floated gangue is carried over the lip by the moving stream of water.

Drying.—This is an important consideration in flotation practice, particularly if the concentrate is to be shipped long distances. The mills, unless indeed they be very large mills with their smelter on the ground, are often as far as 750 miles from the smelter which consumes their concentrates. Every pound of water in the shipped product has to be paid for as freight, hence the moisture content should be low. Often a wet concentrate is not a marketable product as such, and always excess moisture adds extra cost to the labor of handling. The advantages accruing from dewatering and drying lie in the following; viz., (1) by reducing the moisture and thus obviating the paying of freight on water, (2) by preventing the loss of slimy concentrates due to leaking tanks and cars, and the messy sloppage which comes with the handling of wet material, and (3) by avoidance of delay from the freezing of concentrates in cold weather. A difference of 3 or 4 per cent lower moisture content may mean the saving of many dollars in the costs of loading and freight.

The practice of handling flotation concentrates at the Engels mill in California is interesting in its uniqueness. The floated concentrate is first removed to a settling tank outside of the mill building for settling and thickening; the thickened product from here goes to an 8-ft x 8-ft. Oliver filter, which makes a cake containing 10 to 12 per cent moisture. On account of the long distance which this concentrate has to be shipped, namely, to the Garfield smelter near Salt Lake City, it is desirable to reduce the moisture to the loss-by-dusting point—about 5 to 6 per cent. To accomplish this an unused drag-classifier was being remodeled so that heat could be applied beneath it; the dried concentrate is then sacked in canvas bags and loaded via tramway onto a caterpillar tractor for conveyance. Part of the journey to the railroad is accomplished by motor trucks where the roads are good. At the railroad the sacks are emptied into railroad cars for shipment to the smelter.

The Smelting of Concentrates

The new conditions imposed by the character of the flotation concentrates forced a change in the details of furnace operation, and hence the metallurgical treatment of such concentrates is an entirely new subject. In the case of copper concentrates, the product is improved in copper grade and simultaneously in iron and sulphur and impoverished in silica and alumina, when compared with either direct smelting ore or intermediary mill concentrates. The amount of flux required is then correspondingly lessened as the charge is usually more fusible. The extreme fineness; i.e., slime character of flotation concentrates, produces a product in which the alumina (if it be present) is in a colloidal condition and no clay is needed for a binder in briquetting; at the same time, its fineness makes drying and filtering difficult, and its wetness makes briquetting impossible without dewatering. At the Braden mill, Chile, elsewhere mentioned recently, the table concentrate was only fairly fine but was very infusible, due to high silica and alumina; on the other hand, the flotation concentrate was not only very fine and wet but also of a lower silica content which made it more easily fusible.

In regard to the smelting of flotation products there are several methods which have been in commercial use; namely, (1) direct smelting (2) sintering and smelting, (3) nodulizing and smelting, and (4) roasting and smelting.

(1) **Direct Smelting.** This was and still is in part the practice at the Braden mill, Chile, South America. The concentrates were settled but not filtered (this was

previous to the arrival of the filter presses) and charged into the blast furnaces direct. In spite of the fact that the charge was more fusible than before the coke consumption increased considerably. The reason for this was that extra heat was required to evaporate the moisture, and, further, that the wet charge "blanketed," so to speak, and was more or less impervious to the blast penetration. The practice of drying and preheating concentrates preparatory to furnace smelting shows an economy of fuel over charging raw concentrates.

(2) **Sintering and Smelting.** Sintering of flotation concentrates before smelting is comparable to any common sintering operation. At the Herculaneum plant of the St. Joseph Lead Company, already alluded to, the lead flotation concentrate is mixed with the lead table concentrate on a mixing belt, and the mixed product is deposited to sintering machines—Dwight and Lloyd. At the Braden mill, mentioned in the foregoing, the sinter plant consists of four units; each unit is simply a concrete box 50 x 4 ft., on top of which is placed a cast-iron grate similar to a boiler grate. An exhaust fan creates a strong down-draft. The concentrate, spread on the grate in a layer 4 to 6 in. in thickness or less, is ignited by a layer of shavings or sawdust. Once started, the charge roasts from the combustion of the sulphur and becomes agglomerated into a hard cake which is broken into pieces 6 to 8 in. in size. The sintered product thus broken is ready for the blast furnace.

(3) **Nodulizing and Smelting.** Nodulizing is a continuous process which reduces, by roasting, the sulphur content of the concentrates and produces nodules or balls of the roasted charge. A nodulizer consists of a revolvable steel tube lined with fine brick, similar in appearance to a rotary drier of the Ruggles-Coles or other type, 8 ft. to 10 ft. in diameter and from 50 ft. to 120 ft. long. The tube is slightly inclined with a slope of about 1 in. per foot toward its discharge end. Firing is accomplished with oil, gas or powdered coal. In the nodulizer, the concentrate is heated by the firing and also by the burning of the sulphur in part; the charge soon assumes a sticky, viscid consistency and, due to the revolving, rolling motion of the tube, is "balled" into nodules of varying sizes, which are discharged red hot and thence fed to the blast furnace. The nodulizer thus dries the concentrates and reduces the sulphur content to any desired amount pendant on the length of the tube and its diameter; i.e., the time necessary for a unit charge to pass through the tube. The smelting of the nodulized concentrate imposes no new conditions on normal blast furnace operations.

(4) **Roasting and Smelting.** This is best depicted by Anaconda practice as set forth at length in recent technical literature. The installation of flotation at the Washoe Works necessitated the roasting of an augmented tonnage of sulphides, and consequently the roasting plant had to be enlarged. The roasters are multiple-hearth furnaces—seven hearths in all—of the MacDougal type having a shell diameter of 25 ft. and an inside diameter of 23.5 ft. The flotation concentrates and the fine table products are mixed together, thus insuring a uniform roaster feed. The hot calcines are charged to reverberatories. The practice of firing reverberatories with powdered coal has shown a fuel economy over blast furnace smelting; moreover, the reverberatories demand a fine charge so that the development of coal dust as a fuel, when applied to these furnaces, has come in proper time to be of great aid in smelting the fine product produced by flotation.

Resume

Some miscellaneous considerations arise in connection with the disposal of flotation concentrates, hitherto

not mentioned. In regard to the matter of the cleaning and reclaiming of concentrates, two cogent factors enter into the solution of this problem; to wit, leanness or richness of the ore or slime feed and remoteness or proximity to smelters. Here it may be said that on rich feed or where a relatively low-grade concentrate can be consumed economically in a nearby smelter, only one cleaning is necessary; but where a high-grade concentrate with small amount of insoluble is demanded, the dual clean and reclean method is expedient. The matter of the grade of a concentrate may be markedly affected by unlooked-for conditions, as witness the experience of three of the operating companies at Broken Hill, Australia. Before the present great war, a shipping concentrate to Germany demanded a grade of some 47 per cent zinc; any grade below this was subject to penalty. The so-called Broken Hill Associated Smelters Proprietary Company which now has control of the smelting plant at Port Pirie, a distance of some 250 miles from the mines, is taking concentrates as low as 40 per cent zinc.

Still, the production of a high-grade shipping concentrate even for comparatively short shipments usually proves economical in the long run through the savings in freight.

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Mass Screening with Flat Screens

BY EDWARD S. WIARD

Since power-driven machines are more important than stationary or hand screens, and since the power machines have arisen from the attempt to duplicate the motions used with the latter, an inquiry into the results obtained by the motions produced in hand-screening will yield information of value for obtaining the proper ele-

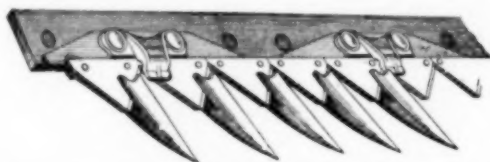


FIG. 1—CODING OF HAND-ACTION IN REAPER

ments for machine screening in mass. The steps by which the body, or more particularly the hands, aided by simple tools, perform mechanical operations, and the thought of the inventor that transfers these steps into mechanical equivalents, have been termed by one writer, "coding."

As an example of coding there is the operation of cutting grain with an edged tool. To do this efficiently by hand, the stalks must be struck with a single hand by a sickle at a point close to the ground; or else a bundle of the stalks must be grasped in one hand and struck below this hand with the sickle in the other. In either case the stalks are held sufficiently immovable so that the cutting blow can be effective. In coding these steps for application in a reaper, the first point which will be recognized is that the single sweep of the sickle is too limited in radius; or if the sickle be made sufficiently long, resembling a scythe, the forward advance of the reaper would cause certain portions of the area swept out by the scythe to be passed over during the drawing back period of the blade. Such a blade would also be very dangerous, and the danger would increase the more rapidly it moved, a very fast motion being imparted to it to reduce the uncut area due to the advance of the reaping machine. But the principal objection to a long blade would lie in the requirement that it would have to hew close to the ground to obtain the hold necessary

for efficient cutting, and the inequalities of the surface would prevent this if it were incorporated in a reaping machine.

The universal coding of the hand action for reapers is shown in Fig. 1. A fixed member holds the stalks against a reciprocating knifed saw blade. It is said that Obed Hussey who, with Cyrus McCormick, invented the modern reaper, originated this element; but it seems older than this, an English patent having the element prior to the year 1800, while Hussey's patent is dated 1833.

Another example of coding, somewhat farther afield from hand action, lies in machine sewing. The simplest hand stitch is of the type where the needle with the thread is forced through the fabric from side to side. This action has been imitated in certain classes of stitching machines which employ a double pointed needle, the eye being in the center. The turning of a point of a needle with an eye in the butt back to the original position, as is done in hand sewing, offers insuperable difficulties from a mechanical point of view. Hence, sewing machines are of two types, in both of which auxiliary means are employed below the surface of the fabric or the surface on which the fabric is laid, to secure the loop forced through by the needle.

It may be remarked before closing this subject of coding that patents fall roughly into three classes. In the first, hand or bodily actions are strictly imitated. In the second, the results of hand or bodily actions are obtained, but mechanical means are introduced which are impossible to the hand or body. In the third class of patents, results are achieved which are entirely outside the domain of human muscular movements. An example of the first class is the steam-power hammer. The sewing machine and shoe-making machinery exemplify both the first and the second classes. The invention of the electric light, carbon arc, etc., are examples of the third class. The intelligence displayed in the three orders of invention are about in the order of their statement, but so far as the sum of human good goes the first two classes preponderate.

Mechanical Screening Coded from Hand Actions

The operation of mechanical screening is directly the outcome of coding hand actions with a hand screen, though often the thought of the inventors as disclosed by patent office records is obscure.

So far as dry hand-screening goes with fairly heavy material, the best result is obtained by a sidewise, slightly rocking fast, uniform motion from right to left, continued for three to ten strokes, followed by tapping sharply on the working bench. With coarse material, tapping is not so necessary. The sharp, uniform motion prevents the grains from partaking of the motion of the screen, and the latter slides under the grains. At the end of each half stroke the mass on the screen tends to pile up against the side of the screen; and to prevent this and spillage, the screen is slightly tilted, an operation which is done quite naturally. A rotary motion of the screen is of very little effect since there are retardations and accelerations in this kind of motion, and the grains have a chance to take up the motion of the screen. No screening will be done and time will be lost.

The next thing which will be noticed in hand screening is that a certain depth of bed gives the greatest capacity. Why this is so, is primarily because of the time lost in transferring small masses to the screen. As the amount placed on the screen increases, a point is reached where the operation of screening is unduly prolonged; that is, a certain depth of bed is reached where complete screening action ceases. The finer the material fed to the screen, the shallower must be the bed to ob-

tain the best screening action. When screening in a mass, the principal action is an interstitial one which brings the fine grains to the screen first, and successively coarser ones, so that with prolonged shaking the finest particles go through first, followed successively by the coarser.

To understand this action reference should be made to Fig. 2 which shows diagrammatically the amount of interstitial opening, or amount the grains part from one another under the shaking action. A-B would represent the amount of opening at the top of the mass of material on the screen, while at O where the mass is in

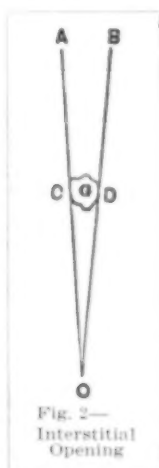


Fig. 2—
Interstitial
Opening

contact with the screen the amount the grains part from one another is zero, or very nearly zero. A particle such as G would pass down through the interstitial opening thus created to the position C-D, and evidently finer particles can proceed down farther, until a particle of no sensible diameter would arrive at the surface of the screen. The first few shakes of the screen would complete this action, giving the



Fig. 3—
Gradation of
Particles

mass on the screen the appearance shown in Fig. 3. To some extent this regular gradation, from coarse at the top of the mass to fine at the bottom, is altered by the position of the grains as they occur in the mass at the beginning of shaking; but the more prolonged the shaking the more perfect will be the gradation, for the coarse pieces are brought to the top of the mass. With any range of size, however, if the bed on the screen be of too great depth, motion tending to open the grains at points near the screen ceases. So long as there is interstitial action, screening with a deep bed will yield commercial results which approximate those obtained by screening with a bed one grain deep.

Deep and Thin-Bed Screening

To put the matter in the simplest form, let the motion of a mechanical flat screen be such that the undersized grains advance in a mass 10 grains deep. Then evidently grain number one, counting from the top, will have no chance to come over an aperture until grains 2, 3, etc., have been eliminated. If the motion of the screen advances the material at an amount per stroke such that one grain of undersize is eliminated at each stroke, then grain number one will have to pass over ten apertures before it can go into the undersize. If the material be fed one grain deep, all the grains under the same conditions, as has already been recited, will be eliminated at one stroke and the capacity per unit of surface will remain unchanged. The disadvantage of deep-bed screening for precise work lies in the fact that as the bed advances toward the discharge edge of the screen it becomes, with respect to undersized grains, more and more to consist of grains near the size of the openings. Undersized grains not in contact with the screen will pass into the oversize due to disadvantages of position.

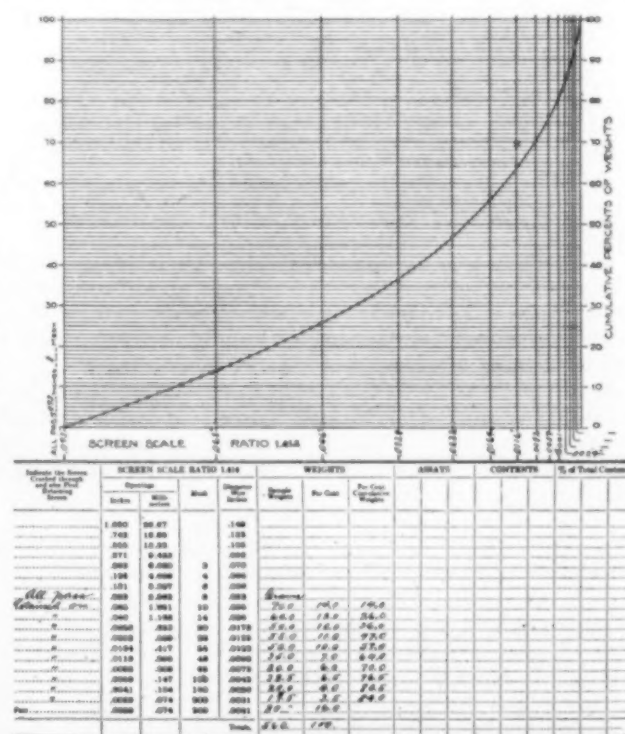
A minor advantage of having the bed as thin as possible lies in the ability to make the motion of the screen such that the grains in their passage over the screen will be thrown into a multitude of axial positions which will be helpful in eliminating the undersized grains if

there be much irregularity of shape. Cork particles, while presenting very irregular surfaces, are roughly cubical; and if a screening device were used which gave them an upward component of motion as well as a forward one, air currents would be created through the apertures tending to buoy the undersized particles and prolonging their elimination. Consequently, for grading cork, various types of bolting machines are used in which the motion of advance is all in one plane. If the motion of the screen be such as to create an active tumbling about, some products would be injured by breakage or crumbling. As examples of this may be mentioned green peas and friable material such as coal, etc. Blinding of the apertures of a screen occurs both in wet and dry screening.

Where crushed material is being screened it will be evident from inspection of the curve shown in Fig. 4, that as the weight increases from size to size the more finely the material is crushed, the number of particles increases much more rapidly than figures which would be proportional to the cube of the reciprocal of the diameter. On the other hand, the number of apertures per unit of screening surface increases only as the square of the reciprocal of the side of the aperture. Consequently with finely crushed material there is always a greater number of particles of very nearly the size of the aperture which will become jammed therein, producing blinding. Again, in reducing material by crushing, as the sizes become successively smaller, types of machines have to be used in which grinding actions become increasingly evident. This tends to put many faces on the grains, thus affording them more opportunity to become firmly lodged in the apertures of the screening machines. Means for reducing blinding will be discussed at a later point.

Advantages of Wet Screening

The majority of the products occurring in the grading industries are produced by machines which treat them dry. In the ore milling industry of the West, however, there are some advantages in screening the ores wet. Wet hand-screening is found to be very effective.



tive for fine material, but where the coarsest particle to be screened is $\frac{1}{4}$ in. or larger, screening can be done just as well dry as wet. The only advantages of wet screening are the washing off of a coat of dust which may adhere to the grains, and the use of water for transporting the oversize and undersize products from point to point in launders. This permits of a cheap mode of transportation and much less loss in head room.

Now in hand screening in a suitable vessel to hold the undersize and the water to aid in the operation, the thing noticed at once is that unless the mass on the screen is occasionally stirred with the fingers, little or no screening action takes place. Again if the screen is pushed down too deeply in the water the effect is not so good as where it is pushed down to a position where the bed of particles is barely or slightly submerged. An up-and-down or jiggling motion of the screen is not so effective as this movement followed by sidewise movements. The jiggling movement alone brings the coarse particles to the screen while the fine go to the top, but it is very effective in keeping the bed loose. The sidewise motion, while very effective for bringing the fine particles to the screen, has a tendency to cake the bed down on the screen, when of course no further screening action ensues. The principal good effect of the jiggling action is the loosening one, followed by the draining away of the water through the apertures carrying with it undersize particles. If the screen be too deeply submerged the water cannot drain away under the jiggling strokes and this useful effect is lost.

In coding the hand actions great difficulties are at once encountered. If it were possible to feed the grains in a mass one grain deep, which is impossible with fine material, submerged shaking screening would be in no wise superior to dry screening. Consider a flat screen submerged in a vessel of water, and to which to-and-fro movements are imparted to advance the material. If the apparatus be started with the proper amount of submergence so that the bed is partly or just submerged, the action of the screen will create waves which will destroy the stratifying action, bring a considerable volume of water above the bed, cause the latter to cake down on the screen and entrap the water above it. If the screen be made stationary, and means be provided such as a drag for moving the material along the screen, then the useful interstitial or stratifying effect is lost and the effect is no better than with dry screening. The loosening effect of a jiggling stroke introduced occasionally is also wanting in this type of apparatus, and to introduce it would add much extra complication.

Other difficulties which are encountered in coding the hand actions, and which are wanting in the latter, are the disposal of the under- and oversizes. If the undersize be allowed to flow from the bottom of the tank, the opening must be sufficiently large to prevent clogging and this will require excessive amounts of water. If mechanical means are used to remove the undersize, it adds to the complexity of the design. If a flat screen be employed, it is quite evident that much of the water will spill over the end of the tank unless some special form is used. Thus J. M. Callow's patent (788,246, April 25, 1905), shows a shaking screen with a small upturned, hinged portion at the discharge end, and evidently a screen with an upturned curved portion at the discharge end would give the same effect. Wet screening without submergence on flat screens is very inferior to dry, because the water drains away quickly, leaving a balled-up, sticky mass, which is difficult to progress over the screen. The overcoming of this action by the Callow belt screen marked an advance in the art.

When all the difficulties are stated, however, there

seems to be no reason why a perfectly successful submerged screen might not be devised which would be very effective and have large capacity.

Mechanical Features of Screens

Screens may be divided into two types: First, those on which the feed advances in a more or less horizontal sheet or in an inclined sheet; and second, those in which a revolving motion is imparted to the feed.

Under the first type there are the following principal varieties. (a) Stationary, and flat or inclined shaking screens. (b) Endless-belt screens, both horizontal and inclined. (c) Rotary flat screens, the means for advancing the feed being centrifugal force. The surface of screens of this variety is a plane, of more or less concaved annular surface. (d) Gyratory screens. These have flat surfaces, and in the flour-mill type, or bolter, the screening surface is rotated in a horizontal plane. The Cox gyratory screen, intended primarily for coal, is mounted on double cone rollers which give a rocking motion to the gyratory movement. (e) Batteries of corrugated cylinders mounted with their axes parallel and in a horizontal plane, have been proposed and used for grading coal or other friable material. The cylinders rotate in a direction to advance the coal, and the undersize falls through the spaces created by the corrugations which match one another on the various cylinders. By diminishing the depth of the corrugations a series of gradings can be obtained. (f) Revolving vertical cones, or stationary cones fed by a revolving horizontal plate.

The second type includes all varieties of revolving screens, or trommels, which are usually placed with their axes horizontal or slightly inclined; although highly inclined cones have been used for this purpose.

The flat shaking screens are of two kinds: those employing perforated metals or screen cloth and those having shaking bars of different shapes. Where a backward and forward motion is employed to advance the material it must be of a differential character or else the screen must be inclined. One way of securing differential is to have the screen moved by a pitman through a pair of toggles, one seat of one of the toggles being fixed and the other connected to the screen in such a way that when the toggles are at the lowest position the screen is at the extreme forward point and moving forward fastest. The simplest differential is one that imparts to the screen an accelerated forward motion and a retarded return. This motion gives the grains a chance to partake of the motion of the screen, while on the quick return they continue to advance. If the motion of the screen was uniform backward and forward it would be impossible for the grains to pick up the screen motion and they would merely roll or slide over the screen under the actuating movement. If a bumping device be used, the kind of motion toward the bumper is not of much moment, since with any kind of forward movement the grains will have picked up some forward movement; and on the screen being brought up sharply against the bumper they must continue to advance. The disadvantage of the bumper device is that it sets up destructive shocks in the screening mechanism.

Counterbalanced Shaking Screens

It is quite essential that shaking screens be balanced to prevent destructive vibration to the framing. This can be done by counterbalancing as shown in Fig. 5, the only requisite being that there be an amount of momentum in the counterweight equal to that of the screen. By increasing the length of leg of the counterpoising portion of the system the counterweight can be

decreased to any desired degree, for evidently in any case the weight of the screen through the space passed over, or its velocity, must be equal to the weight of the counterpoise through the distance over which it passes, or its velocity, during a stroke. Theoretically, of course, the balanced system having twice the mass will require twice the power to actuate, but this is more

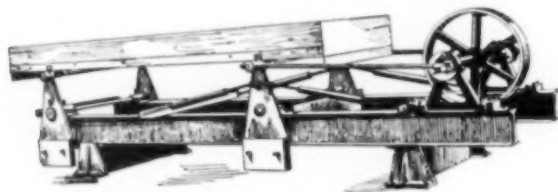


FIG. 5—BALANCED SHAKING SCREEN

than compensated by less friction due to unbalanced thrusts on the bearings or pivots of the screening machine. Another mode of balancing is to have two screens moving in opposition to one another. All grain-cleaning separators, Fig. 6, are thus arranged in pairs, and the remarkable smoothness and freedom from vibration of flour-mill or grain-elevator separators is noticeable at once to an observer. The Coxe shaking grizzly, which is shown in Fig. 7, has two sets of bars moving backward and forward in opposition to one another, thus securing almost perfect balance. The bars have an elliptical motion, the longer axis being forward and the shorter an upward component. These bars are much used in the anthracite coal regions of Pennsylvania and on this class of material they have a capacity of 3.65 tons per 24 hr. per square foot of bar area. Advance of oversize grains is secured by their straddling two bars of a set which are moving forward at any time; and when bars of the second set come up through in their forward motion, they also carry the particles ahead an additional amount, and so on until discharge.

Disadvantages of Flat Moving Screens

Plain revolving flat screens with the screening surface in a horizontal plane have the disadvantage that the motion of the grains from the center where they are fed to the periphery is very nearly along a radial line; and as the motion of the grain accelerates very rapidly, the chance of its falling through an aperture consequently diminishes as it proceeds toward the periphery. To offset this, centrifugal screens are sometimes made with concave curved surfaces to retard the motion, the oversize spilling over the lip of the screen

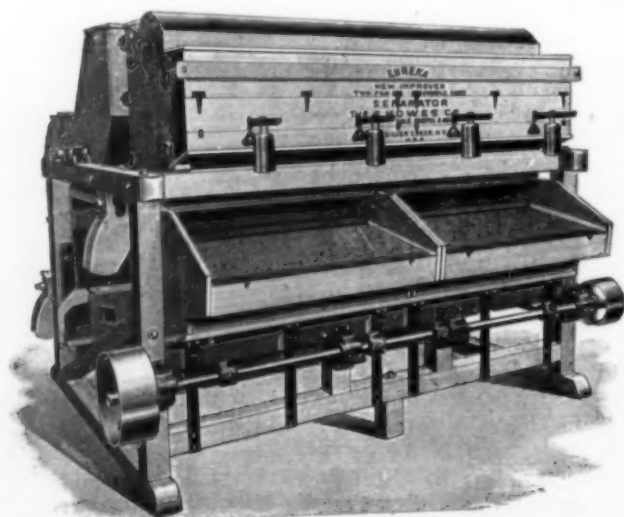


FIG. 6—ARRANGEMENT OF FLOUR-MILL SCREENS IN PAIRS

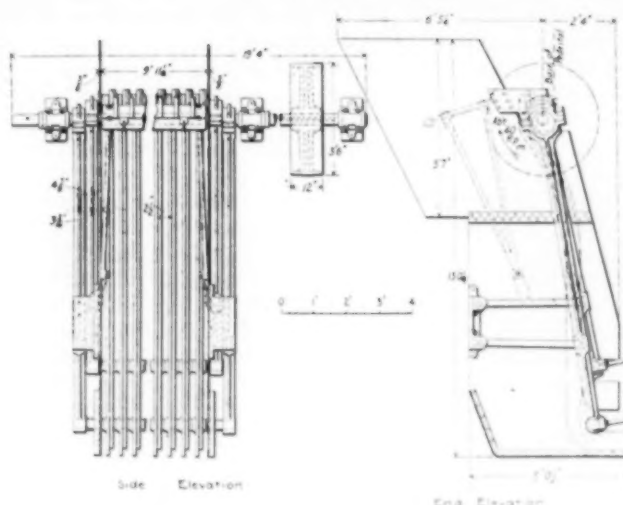


FIG. 7—COXE SHAKING GRIZZLY

which is curved up sharply at the discharge edge. Plain rotary screens of this type have an advantage in that they need no balancing; but the tendency of the grains to be continually in motion is not good from the screening point of view and not so good as in a reciprocating screen where the grains have a chance to come to rest at the end of the stroke. Also, where the grains are not isometric, longish and flattish grains have very little chance of disposal in the undersize where they may belong. Gyratory types, of which the best examples are probably the bolters used in the flour-milling industry, are essentially flat screens arranged in parallel batteries, and to which a gyratory motion is given. The outlines of the machine are rectangular when screens of this shape are employed, or cylindrical when circular flat screens are used.

Means for balancing gyratory screens can be made quite simple. Thus the bolter of Fig. 8 is supported on two eccentrically placed pins of the flywheels A-A which drive the mechanism. These flywheels carry counterweights as shown in Fig. 9 of the flywheel. In the gyratory devices, while the moving force is centrifugal the grains do not proceed by such direct paths to the periphery of the screen, the motion of the particles being elongated ellipses the long axis of which is directed toward the periphery. With a gyratory motion every point describes a small circle. Quite evidently if the speed be too great the grain will not partake of the motion of the screen, and at the end of each stroke it will be practically in the same position with reference to a point on the screen on which it rested at the beginning. If the speed be too low the particle will partake of the screen motion exactly, and at the end of a stroke will be in the same position as before. Between these two limits will be found the one giving the best screen effect, for evidently as the speed is increased between these limits, the centrifugal or discharging effect will increase; but if this be too great the grains will have little or no chance in passing through the apertures. Gyratories give a greater length of path without reducing the rate of advance. They have a speed of 130 to 180 r.p.m.

Gyratory devices of the bolter kind are advantageously used in flour milling, for the gentle rubbing action of the silk on the broken wheat berry tends to rub the flour through the sieve. Bolters are also used for grading ground cork, for reasons already explained.

Merits and Demerits of Revolving Screens

Revolving screens are made in cylindrical, conical or polysided shapes. The conical or pyramidal screens

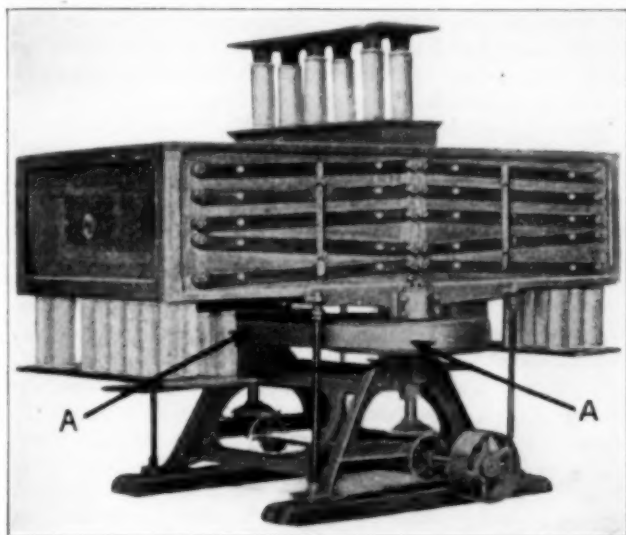


FIG. 8—BALANCED GYRATORY SCREEN

have the advantage that the axis can be placed horizontal; but the disadvantage is that the screens have to be made in a special shape which involves complications in securing the screen to the frame. With practically all horizontal or nearly horizontal revolving screens, the screen proper is supported on spiders and this in turn on a central longitudinal shaft resting in bearings. If the frame of the screen be such as to require a conical clothing, the tires of the spiders must be inclined to the spokes; and if the hold of the screen cloth or plate be by friction, as it is except with the pyramidal shapes, there will be more tendency for the screen to become loose than with cylindrical forms.

The conical and pyramidal shapes can scarcely be said to be an advantage, for there is no gain in head room by their use; and since the best method of drive is through bevel gears, the screen with inclined shaft is at no greater disadvantage on this point than one with horizontal shaft. If the material to be screened has sufficient hardness to produce rapid wear, the spiders must be frequently renewed; and in the case of conical or pyramidal trommels this entails keeping on hand a large stock of spiders of different sizes. The conical and pyramidal shapes have the further disadvantage that they have less

screen area for the same room occupied in housing. A conical screen 6 ft. long and 36 in. diameter at the discharge end will, with a taper of $1\frac{1}{2}$ in. to the foot, have a diameter of 18 in. at the receiving end, and the area of screen surface will be about 6158 sq. in. A cylindrical screen 6 ft. long and 36 in. diameter, and whose housing will occupy no more space than that of the conical screen, will have 8142 sq. in. of screening surface. The largest pyramidal screen of six sides which can be enclosed by the truncated cone will have 5864 sq. in. of surface. But the diminished screen surface will be more serious than indicated by the figures, since at the angles there must be frame members and these will reduce the net area 5 or 10 per cent. I have not taken into account the blind



FIG. 9—COUNTERWEIGHTED FLY WHEEL

areas produced by intermediate spiders in any of the cases.

Friction-Roller Drive for Revolving Screens

The usual means of support has been stated to be by spiders and shaft. Dry screens have, however, been supported on four friction rollers or by two rollers and a shaft and gudgeon. At first thought the mounting of the screen on friction rollers would seem to be the ideal way of supporting it. The housing can be made very nearly as simple as for revolving screens supported by central shaft. All the wear comes on the screen surface proper, there being no necessity of replacing worn spiders from time to time, a condition which arises when screening rock and ore. If a wet screen be employed the water may be introduced inside the screen, and not on the outside as must be done with screens with spiders. When the water is introduced outside, most of it is wasted, and often does harm, as in grading ores for separating machines.

The simplest form of friction roller screen would consist of two narrow rings to which would be secured the screen cloth or plate, and four friction rollers. The rollers might be single or connected in pairs by shafts. To drive this mechanism, power would have to be applied to a roller or pair of rollers, motion being given to the screen through frictional contact. Such a means of transmission, however, would be impractical; for even assuming that the only power consumed would be for overcoming the friction in the roller bearings, and further that the screen is perfectly balanced at all points in its circular motion and that hence when the screen is in motion no power is required to rotate it, the starting torque would be sufficiently great to cause the tread rings to slip on the rollers.

It is common to drive these screens either through an enveloping ring with sprocket or gear teeth and by a sprocket chain and pinion, or a gear pinion, or else through a bevel gear. The advantage of the first two modes of drive is that there is a clear space through the screen from end to end; while with a gudgeon and bevel-gear drive, slots must be cut through the sides of the gudgeon to permit the oversize to discharge, and as the gudgeon is a fixed piece this portion will have to be renewed from time to time at some expense owing to wear. On the other hand, the gudgeon arrangement permits of somewhat lighter details, the bevel wheel being of small diameter and affixed to the face of the gudgeon, and in a position where it is less likely to be attacked by grit and dust than the form of drive employing an encircling driven wheel.

Relative Power Consumption of Revolving Screens

The four-wheeled friction mount consumes more power than a revolving screen supported on shafts, or one employing two friction wheels and a shaft and gudgeon. With imperfect lubrication such as obtains with plain bearings lubricated by grease cups, the

power consumption of the central bearing is $\frac{fW\pi DN}{2}$

which evidently increases as the diameter of the shaft, other things being equal. In the formula, D is the diameter of the shaft in fractions of a foot, N the number of revolutions per minute of the shaft, f the coefficient of friction, and W the pressure on the bearing.

If H' be the horsepower consumed by a screen of weight W , revolving on friction rollers at N revolutions per minute, and H be the power consumed by friction of a screen of the same weight revolving on a central bearing, also at N r.p.m., then

$$\frac{H}{H'} = \frac{D' 0.707}{D'' \cos^2 \theta}$$

where D' is the diameter of the revolving screen, θ one-half the angle made by lines passing through the center of the screen and the centers of the friction rollers, and D'' the diameter of the friction rollers. In this formula the factors of the size of the shaft of the friction rollers and the central shaft are eliminated by making them of the proper proportions to support the same load. In the derivation of this ratio also, the resultant forces acting on the bearings are assumed to be in the line of action of the weight of the screen, in the case of the central shaft; and in the case of the friction rollers, in the lines of the components of the weight. They vary from that line by an angle whose tangent is f , the coefficient of friction.

It will be seen at a glance how much more power is consumed in bearing friction with friction rollers than with a central shaft, which is contrary to common belief. The confusion of thought results from reasoning by analogy from the type of bearing which used to be more commonly employed than at present; for example, where a shaft was mounted on a pair of friction rollers placed as close together as possible; for, as an inspection of the formula will show, the closer the wheels are together the less will be θ and the greater the value of $\cos^2 \theta$, or, the less the numerator and the less consequently the value of H . Such a type of bearing was commonly used on grindstones. Here, if the shaft was 0.5 in. diameter, the value of the numerator would be 0.354. If the friction wheels were but 3 in. in diameter and θ was 30 deg., the value of the denominator would become 2.25; or the ratio H to H' would only be about 1/3, making of course an appreciable saving in power.

Denver, Col.

Corrosion and the Engineer*

BY W. H. WALKER

In the valuable contributions of Dr. McCullom and his co-workers at the Bureau of Standards upon the corrosion of iron structures when buried in the ground, a terminology is employed which is very useful in discussing the damage occasioned by stray electric currents, as contrasted with that caused by the natural corrosion of the iron unaccelerated by an external electromotive force. But while it is logical to call the first type of corrosion "electrolytic," because induced by the flow of an impressed electric current, it is, however, illogical to describe the latter type as "self-corrosion" because of the unavoidable inference that it is not electrolytic, but is purely chemical in its nature. It may possibly be due to this lack of a clear conception of the mechanism of natural corrosion on the part of the electrical and mechanical engineers that is due the fact that they have displayed so little interest in the subject, and have so tardily availed themselves of the knowledge of the phenomena now at their disposal.

In dealing with problems of corrosion the engineer is satisfied if he can explain a phenomenon by stating "that a galvanic cell is set up." Thus a piece of coal in contact with an iron plate or a bit of mill scale on a pipe will cause a pit to form "because it sets up a galvanic cell." From a chemical point of view both the coke and the mill scale are perfectly inert; how then can they cause galvanic action—what rôle do they play in the solution of the iron which produces the pit?

Eight years ago it was my privilege to present before this society a paper on the function of oxygen in the

corrosion of iron¹ in which I offer an explanation for the galvanic action of such inert bodies, and made some applications of the facts described to general engineering practice. Time has shown that the conclusions here drawn were correct. But obviously this paper was not so clearly written, or the facts were not so convincingly told as to attract the attention of the engineering fraternity to it, or at least to occasion any discussion of it. Engineering magazines continue to publish lengthy articles upon the pitting of boiler tubes, the rusting of water supply systems, the red water plague, anti-corrosion compounds and the like. These papers described the symptoms and generally prescribe a cure, but say never a word as to the cause of the trouble.

What would be thought of the medical profession, for example, if it continued to write only regarding the drugs to use in a case of typhoid fever but did not interest itself in the cause and its removal? As a matter of fact, this is an age of preventive medicine. We sterilize the water and inoculate the man in order to prevent the malady. Not so the engineer. He continues to drug his boiler or physic his hot-water-supply system in a vain attempt to cure the disease, but takes no steps to prevent it. He gives whiskey and quinine to help a neurasthenic, when luckily he cures a bad, but unsuspected, case of chills and fever.

Within the last few months there was presented before our largest national engineering society by an electrical engineer a paper which contains data exceedingly important to the profession and which are none the less valuable because old. We gladly recommend this paper² to all who are interested in the corrosion of steam boilers, especially the truly novel portion which consists in recommending a constant observation of the water in the boiler itself, by the engineer in charge, and not simply a study of the feed water alone by some absent chemist. However, the paper would have been increased in value manyfold if the author had studied his problem from the point of view of the cause of his trouble and showed the existent relationship between the cause and the cure. In fact when he essays to mention a cause he falls into grievous error. For example, he states: "but it is very evident that the low osmotic pressure of distilled water is the direct cause of the corrosion." Now of all the factors influencing corrosion osmotic pressure from whatever source is the least active—is in fact practically negligible.

Corrosion is an electrolytic phenomenon and can be understood by electrical engineers on purely electrochemical grounds. It takes place at ordinary temperatures only in the presence of water through the reaction



This means that a metallic iron atom electrically neutral interacts with two hydrogen ions present in the water and which carry electrical charges; the result is the production of an iron ion which takes up the two electrical charges from the hydrogen ions and the deposition of two atoms of hydrogen. Energy is lost to the surroundings and appears as electricity and heat.

The factors which influence the action are, first, the *solution pressure of the iron*. This is constant for all samples of iron under constant conditions, but may be influenced by a number of agents. Thus the immunity of iron to corrosion in solutions of chromic acid is undoubtedly caused by the passivity of the iron—a thing which, whatever its true nature, is equivalent to lowering the electrolytic solution pressure of the metal.

The impression of an external emf. may also be considered as equivalent to a change in solution pressure.

*A paper read before the New York Section of the American Electrochemical Society in joint session with the American Institute of Electrical Engineers on March 10, 1916.

¹ELECTROCHEM. AND MET. ENGL., vol. VI, p. 492.

²A novel method of handling boilers to prevent corrosion and scale. By Allen H. Babcock. Am. Soc. Mech. Eng. 1915.

This may be either positive or negative in its direction. If the potential employed be mechanically generated, we speak of it as "stray currents," but if electrochemical in its origin, it is described as the accelerating or retarding effect of other bodies. Thus iron, which itself is incapable of corrosion when imbedded in concrete, is severely attacked if its solution pressure be sufficiently increased by having superimposed upon its own potential, an external emf. due to stray currents. On the other hand the potential of iron may be so depressed by an impressed emf. due, for example, to the solution pressure of zinc, that the iron in contact with zinc will not corrode.

Second, the number of the hydrogen ions. The greater the concentration, the more rapid will be the corrosive action. Hence, if any substance forming hydrogen such as carbonic acid or bicarbonate, or sulphur dioxide or any acid-forming compound be present, corrosion is accelerated. On the other hand, if an alkaline material such as soda ash or caustic soda be present, the number of hydrogen ions is decreased and corrosion is retarded. If enough hydroxyl (the active ion of an alkaline compound) be present, practically all of the hydrogen will disappear and corrosion will entirely cease.

In the paper on boiler corrosion already cited, the author has simply added another example to the many already existent, which proves that carbonate of soda in sufficient amount will prevent corrosion in the manner just stated. His suggestion that the engineer readily examine the water in his boiler by withdrawing a sample and titrating it with standard acid is a novel one, and highly to be recommended. Full directions for doing this are given in his paper.

Third, the ease with which the hydrogen ion reaches the iron. For example, the wonderful resistance of sheet steel containing small quantities of copper to corrosion when used as roofing is unquestionably due to the adherent nature of the film of oxide produced when corrosion starts. This film, as in the case of the aluminium oxide coat on metallic aluminium, effectually insulates the metal and practically prevents further corrosion.

Fourth, the osmotic pressure of the iron ions. This is so small in any case that it is negligible; in the presence of oxygen it is kept extremely low owing to the formation of insoluble iron hydroxide.

Fifth, the deposition of the hydrogen and its removal by the depolarizing action of oxygen. The accelerating action of metals such as platinum, copper, and lead, and materials such as coke and mill scale upon the corrosion of iron are undoubtedly due alone to the aid these bodies offer to the elimination of the hydrogen produced by the corrosion reaction, owing both to the low overvoltage of hydrogen upon these substances and to the high catalytic action of these materials on the hydrogen-oxygen reaction by which the deposited hydrogen film is removed.

While in specific cases the corrosion of iron can be absolutely controlled by first one and then another of these factors influencing it, too little attention is generally paid to the last one. The retarding action of the hydrogen film which is stable in the absence of oxygen and any acid-forming compound is so controlling that from this point of view, oxygen (or air) may be said to be the cause of corrosion. If oxygen be completely removed from boiler feed water, the boilers will not pit nor corrode. If oxygen be separated from the feed of ordinary hot-water-supply lines, the "red water plague" and other corrosion troubles will disappear.

By this removal of the cause of the disease not only are all its ill effects avoided but the necessity of drugging with alkali, removal of the products of corrosion,

and such curative measures, with their attendant evils are eliminated, and in this as in so many other cases experience has proved prevention to be better than a cure. If the electrical and mechanical engineers will only take more closely into their confidence their brother electrochemists, we can together more quickly make available the knowledge on the subject of corrosion already at our command for the elimination of the difficulties which it introduces into commercial practice.

* * *

The above paper by Professor Walker was presented at the joint meeting of the American Institute of Electrical Engineers and the New York Section of the American Electrochemical Society on March 10 and was preceded by a paper by Dr. Burton McCollum and G. H. Ahlborn on "The Influence of Frequency of Alternating or Infrequently Reversed Current on Electrolytic Corrosion." An abstract of this paper which was read by Dr. McCollum is herewith given:

Influence of Alternating Current on Electrolytic Corrosion

Dr. Burton McCollum and Mr. G. H. Ashburn in their paper on the "Influence of Frequency of Alternating or Infrequently Reversed Current on Electrolytic Corrosion" describe the results of experiments made to determine the coefficient of corrosion (amount corroded divided by theoretical amount) of iron and lead in soil with varying frequencies, with 60 cycles as the maximum and a two-week period as the minimum. The data were obtained as a part of the general investigation of electrolysis conducted by the Bureau of Standards.

Preliminary experiments made with solutions to determine the effect of circulation of the electrolyte on the reversibility of the chemical action, that is, considering that one metal goes into solution when the current is in one direction and is plated when reversed, it was reasoned that rapid circulation of the electrolyte would tend to prevent the replating as mentioned above and consequently a larger coefficient of corrosion would result than in a still electrolyte. These considerations were borne out in the preliminary experiments, and it was also found that the coefficient was higher for the lower frequencies. With iron or lead buried in soil a still electrolyte is encountered so that it would be expected that the corrosive process would be in a large degree reversible even with long periods of time.

A complete series of tests were made both in a jar indoors, and outside in the soil. On account of weather conditions and insulation difficulties it was not found practical to run a complete set of tests outdoors. Tests were made indoors with iron electrodes in normal soil to which sodium carbonate had been added. The same was done with lead electrodes. The outdoor tests were made with iron and lead electrodes but were not so extensive.

The conclusions drawn from the results are as follows:

1. The corrosion of both iron and lead electrodes decreases with increasing frequency of reversal of the current.
2. The corrosion is practically negligible for both metals when the period of the cycle is not greater than about one minute.
3. With iron electrodes a limiting frequency is reached between 15 and 60 cycles per second, beyond which no appreciable corrosion occurs. No such limit was reached in the lead tests, although it may exist at a higher frequency than 60 cycles.
4. With periodically reversed currents, the addition

of sodium carbonate to the soil reduces the loss in the case of iron and increases it in the case of lead.

5. The coefficient of corrosion of lead, under the soil conditions described in the report, when subjected to the action of direct current was found to be only about 25 per cent of the theoretical value.

6. The corrosion of lead reaches practically the maximum value with a frequency of reversal lying between one day and one week.

7. The corrosion of iron does not reach a maximum value until the period of the cycle is considerably in excess of two weeks.

8. The most important conclusion to be drawn from these investigations is that in the so-called neutral zone of street railway networks where the pipes continually reverse in polarity, the damage is much less than would be expected from a consideration of the arithmetical average of the current discharged from the pipes into the earth. Where pipes are alternately positive and negative with periods not exceeding 10 or 15 minutes, the algebraic sum of the current discharged is more nearly a correct index to the total damage that will result than any other figure that can readily be obtained.

9. The reduction in corrosion due to periodically reversed currents appears to be due to the fact that the corrosive process is in a large degree reversible; so that the metal corroded during the half cycle when current is being discharged is in large measure redeposited during the succeeding half cycle when the current flows toward the metal. This redeposited metal may not be of much value mechanically, but it serves as an anode surface during the next succeeding half cycle, and thus protects the uncorroded metal beneath.

10. The extent to which the corrosive process is reversible depends upon the freedom with which the electrolyte circulates, and particularly, on the freedom of access of such substances as oxygen or carbon dioxide, which may result in secondary reactions giving rise to insoluble precipitates of the corroded metal. It is largely for this reason that the corrosion becomes greater with a longer period of the cycle since the longer the period the greater will be the effect of these secondary reactions.

Discussion on Corrosion

This paper elicited an extended discussion in which Messrs. Philip Torchio, Alexander Maxwell, Albert F. Ganz, J. L. R. Hayden, S. M. Kintner, Carl Hering, Asa T. Way, C. B. Martin, Thomas M. Roberts, L. W. Chubb and Thomas Spooner participated.

The discussion of Professor Walker's paper was opened by Professor W. K. Lewis, who had presented the paper in the absence of the author. He showed samples of iron on which by the well-known Cushman-Walker method of indicators the anodic and cathodic regions were clearly and very prettily indicated by different colors. He also mentioned that zinc protects iron from corrosion because it is electropositive to iron; but that aluminium does not protect iron, although one would expect so for exactly the same reason; the reason why aluminium is ineffective for protection is the surface layer of aluminium oxide, which always forms on aluminium surfaces and insulates the aluminium from the solution.

Dr. A. L. Cushman first gave historical notes on the discovery of the indicator method by which the electrolytic nature of corrosion is made visible to the eye. He then referred to the alleged non-corrosive properties of steel containing a small amount of copper. "This is the easiest specification that has ever been offered to the engineering profession. I can go and change a batch of steel into coppered steel by throwing a couple

of handfuls of pennies into the door of the open-hearth furnace. It is a penny-in-the-slot proposition." But Dr. Cushman does not believe in it.

Dr. Cushman then made the first announcement of an extended series of tests which he has carried out on a large scale. Three years ago, in March, 1913, he put out over 300 full-sized 26-gage sheets of every possible analysis of sheet metal that he could obtain for the test. Some were put out in a Western mill town in the midst of smokestacks and chimneys and the clearer air of Washington. He was most careful to see that they were gaged properly and that they were all the same gage; they were not only measured with the micrometer to the best possible extent of gaging full-sized sheets by such a method, but they were weighed individually to see that no great variations of thickness occurred, because this is a matter of prime importance for comparative corrosion tests. These full-sized sheets, which have been out for three winters, are now in his laboratories in Washington, but Dr. Cushman had cut out small samples from them and had brought them along to the meeting.

Out of the 300 sheets which had gone through the exposure tests for three winters, eight had failed, and each one of them is very low in copper. But it would be wrong to conclude that they rusted because they contained no copper. The chief result of Dr. Cushman's tests is that *the factor which primarily controls corrosion is the presence of gases in the metal.*

Gases (oxygen, hydrogen, nitrogen, carbon monoxide, and to a lesser degree carbon dioxide) may be present in steel in three forms, as the atmosphere in a blow hole, or in the state of a solid solution, or in form of an oxide or hydride or nitride or carbon compound.

In the case of the eight sheets which failed out of the 300, the amount of nitrogen alone in them is five times larger than it ought to be by analysis. The nitrogen in the eight samples was 0.014, 0.015, 0.022, 0.017, 0.019, 0.019, 0.011, 0.016; the carbon monoxide 0.011, 0.016, 0.012, 0.014, 0.015, 0.021, 0.013, 0.016 respectively. "Such stuff as that is bound to rust. It is not a question of whether there is copper in it or not."

Dr. Cushman mentioned the case of a particular pipe which failed while the neighboring pipes were getting along very well. That pipe had nitrogen 0.041, while the other pipes had nitrogen 0.004.

Dr. Cushman said he had such a mass of material to back up his theory that it was a question to him how to get it all out and "present it for publication in such manner and in such way as not to do any injustice to colleagues who do not agree with me. I have arrived at that time in life when I no longer cease to respect a man because he believes something I know is not so."

After discussing briefly the problem of detecting gases in steel sheets and the acid test for liability to corrosion, which was once so much favored by some, but less heard of at present, Dr. Cushman concluded that when the whole discussion of the subject will be over "there will be no engineer who is going to believe in the solid specification any more. What he is going to believe in is the properly made, properly gasified metal. Whether he wants extreme purity or not is another question which he will decide for himself as far as the metallic impurities are concerned. But what he is going to insist on, and what he will find ways of determining for his specification, is the gas content of the metals, particularly when he is spending thousands and thousands of dollars of other people's money in buying these metals."

Mr. Maximilian Toch in speaking of a research which he carried out ten years ago on the corrosion of structures embedded in concrete, said he reached the conclusion that the cathode steel never rusted and the

anode steel always rusted when given sufficient freedom, that is, when the pressure of the concrete was insufficient to prevent the reaction; but neither of the two rusted when coated with an alkali-proof insulating paint.

When Mr. Toch investigated the steel and metal of the battleship Maine when the hull was finally uncovered in 1912, evidences of electrolytic corrosion were manifest, and one particular picture of a bronze binnacle stand that was adjacent to a steel ventilator shaft showed that these two had coupled, the bronze being the cathode and the steel shaft the anode, with the result that the ventilator steel shaft was entirely eaten away and the bronze binnacle stand left in perfect condition. On the other hand, we know that cast iron or iron having a coating of silicide of iron is proof against corrosion, for the very pump that was used for emptying the hull of the battleship was the pump which had been subjected to salt water in the hold of that ship for thirteen years, and when it was taken out only a few connecting rods had to be replaced, the balance of the pump being in excellent condition.

Mr. Toch finally pointed out that iron and steel rusts progressively, but zinc and lead do not. In Belgium roofs are protected with zinc plates, which turn white by reason of the fact that a very fine film of hydrated oxide of zinc is formed, and once this coating is formed no further corrosion takes place. "I am working on this very interesting problem now because iron or steel rusts progressively, which has led me to the conclusion that there may be anodic or cathodic forms of rust," and one form may continue to rust and the other form become immunized.

Mr. Frank N. Speller, in a communicated discussion on the corrosion of water pipes, pointed out that corrosion inside a pipe was quite different from the corrosion of the outside of the pipe in contact with the soil. The degree of aeration of the water is the controlling factor in hot-water supply lines, so that it is of first importance in designing systems where iron pipe is used to provide for the removal of as much of the free oxygen and carbonic acid as possible.

Based on this principle, Mr. Speller has designed and constructed two plants in Pittsburgh for removing these gases from hot water by allowing the water to pass through thin sheets of black iron spaced about one-fourth of an inch from each other, presenting about 100 sq. ft. of surface per cubic foot of space. The corrosive gases are entirely eliminated by a few minutes' contact with these plates at a temperature over 160 deg. Fahr., and are removed at a slower rate at a lower temperature.

Mr. James Aston, in closing the discussion, emphasized the great effect which rust already formed has on the continuation of corrosion.

First—Rust has an effect on the electrode relations at least equal to that of factors recognized as most serious. The potentials are no less than those of iron-carbon, or iron-copper couples, and in this respect the effect of rust is much greater than that of mill scale or cold rolling.

Second—The rust, wet rust at any rate, does not act as an electrode, but rather as a diaphragm which allows penetration of the moisture and prevents or slows down oxygen access to the coated iron surface. The covered iron is the anode and goes into solution, while the iron to which there is more free oxygen access is the cathode and is protected. This is contrary to general understanding.

Third—Rust plays a dual rôle. Fresh wet rust always creates a condition anodic to bare iron, while dried rust is equally cathodic, with a tendency toward re-

versal of polarity on thorough soaking with water. The reversal period varies greatly, from a minute or less to hours or days, depending upon the characteristics of the rust.

That rust is an accelerator of further rusting is a foregone conclusion from the preceding argument. The reversal on drying out serves only to spread the rust, while non-reversal tends to concentrate the effect in localized zones and causes pitting.

It is in the latter effect that the influence of rust is probably of greatest weight, particularly in water-service pipe lines, where the rust has no opportunity to dry out. It appears likely that much of the spread of rust and pitting observed is due to the influence of the rust itself, rather than to inclusions in iron which may soon be covered and obscured.

The Technical Production of Hydrogen and Its Industrial Application

BY HARRY L. BARNITZ, PH.G.

Prior to the year 1907 little importance was given to the technical production of hydrogen gas. Since then, however, the application of hydrogen gas has been continuously and rapidly extended. With the development of the dirigible airship in Germany, it was imperative that hydrogen be cheap and easily obtainable in large quantities. Accordingly the development of the airship may be considered the chief stimulus in the technical production of hydrogen. Germany, France and England have been the principal countries to first utilize the gas commercially. To Germany credit must be given for being the first, not only in developing its technical production, but also in extending its application. In the United States, hydrogen is continually increasing in importance in the industries, but prior to 1913 only little was used.

For the autogenous welding of steel, cast-iron, wrought iron, copper and aluminium and its alloys, hydrogen in combination with oxygen is finding continued increasing application. Hydrogen here presents the great advantages of wide applicability, cleanliness, and cheapness. Another use which is constantly extending is in the cutting of wrought iron and steel. The oxy-hydrogen flame will cut metal up to 24 in. in thickness. In the cutting process considerable excess of oxygen is required, whereas in the welding process a reducing gas mixture is used. The cuts are cleaner than those of a saw, and even in thick metal are only $\frac{1}{8}$ of an inch in width. The rapid extension of the cutting practice by the oxy-hydrogen process is due to its convenience, simplicity and cheapness. The oxy-hydrogen flame is also used for melting quartz and platinum in lead burning, in the manufacture of synthetic jewels such as ruby and sapphire, and in many other technical processes.

In the manufacture of electric lamp filaments hydrogen finds further employment. Large quantities are used in the reduction of tungstic acid and in the sintering and fusing of the tungsten metal powder into rods.

Hydrogen produced by the silicon, aluminum and other similar processes costs from \$5.20 to \$6.85 per 1000 cu. ft. These processes have been displaced by practically three patented processes known as the contact-process (iron process), Rinker-Wolther process (oil process), and the Linde-Frank-Caro process (water gas process). The cost per 1000 cu. ft. varies from 54 to 61c. in these three processes. These figures are given on the basis of prices ruling in Germany. In plants of similar construction in the United States the cost of production is between 85c. to \$1 per 1000 cu. ft. In the United States only four plants of the newer type have so far been installed: two plants of 3530 cu. ft. per hour,

one of 10,600 cu. ft. per hour, and one of 8000 cu. ft. per hour. Over fifty electrolytic hydrogen plants have been installed in the United States in the past five years, and the total amount of hydrogen now being generated by all processes per year in the United States is over 300,000,000 cu. ft.

The number of mechanical and chemical plants of the improved type erected in Europe up to the summer of 1914 (that is, up to the time when the war broke out) was 23, of a total capacity of 3530 to 10,600 cu. ft. per hour. Three of these installations produce 200 to 880 cu. ft. per hour. All of these plants in Germany, Russia, Austria, Sweden, Holland, Italy and England were installed by Germans. Other large installations were negotiated for, but the writer is unable to ascertain facts regarding them due to conditions at present in Europe. No doubt Germany has increased its hydrogen-producing plants; likewise England, France and the other countries. New installations were undoubtedly required for the increased number of airships and observation balloons which have been built during the war.

Modern Processes of the Technical Production of Hydrogen

LINDE-FRANK-CARO PROCESS—A PHYSICAL LIQUEFACTION WATER GAS PROCESS.

In this process water gas, consisting almost solely of carbonic oxide, CO, and hydrogen, is cooled and compressed until the carbonic oxide is liquefied, while the hydrogen still remains gaseous and can be drawn off. The apparatus consists essentially of a water gas plant and a plant for the separation of the hydrogen from the carbonic oxide gas.

The water gas is produced in the usual way by passing steam through incandescent coke, whereby the steam is decomposed, its oxygen forming carbonic oxide with the carbon of the coke, while its hydrogen remains free. Water gas, on the average, consists of hydrogen 50 per cent, carbonic oxide 40 per cent, carbonic acid 4 per cent, nitrogen 5.5 per cent, methane 0.5 per cent, with smaller proportions of oxygen, sulphuretted hydrogen, and carbon bisulphide.

The hydrogen is separated from the rest of the gases by compression and cooling. The boiling point of hydrogen, -253°C. , is much lower than that of the other constituents, that of carbonic oxide being -192°C. , and that of nitrogen -196°C. On cooling compressed water gas to the temperature of liquid air, -193°C. all of the constituents except the hydrogen are liquified. The hydrogen thus easily separated in the gaseous state is of a high degree of purity.

Before this separation by cooling is attempted the water gas undergoes preliminary treatment for the extraction of carbonic acid, which, if not removed, would block the narrow tubes of the rectifying apparatus. The removal of the carbonic acid gas is affected for the most part by compressing the water gas, in contact with cold water, up to a pressure of about 12 atmospheres. At high pressures water absorbs carbonic acid more easily than at atmospheric pressure, and hence the quantity of water required for absorption is reduced. The small residue of carbonic acid still remaining in the water gas is extracted by passing the latter through caustic soda.

This method of compressing water gas and cooling it by liquid air produces hydrogen 97 to 98 per cent pure. The residue consists of about 1 per cent each of carbonic oxide and nitrogen. Sulphur, dust and moisture are absent from the gas. The hydrogen leaves the apparatus under a pressure of 25 atmospheres, which is a considerable saving of power when cylinders have to be filled with gas under pressure. Two to four men can

operate a plant, depending on its size. The plant is kept in continuous operation for about a week; it is then advisable to shut down the hydrogen separating section in order that all the worn tubes may be cleaned. A second unit of this section of the plant is kept in reserve for use while the first unit is being cleaned. To bring the entire plant into operation requires twenty to twenty-four hours.

THE CONTACT PROCESS—KNOWN AS THE LANE OR IRON AND STEAM PROCESS.

This process depends upon the well-known property possessed by incandescent iron of decomposing steam which is passed over it. The oxygen of the steam combines with the iron and the hydrogen is liberated. In the practical working of the process reduced iron ore is used which has the advantage over ordinary metallic iron of having a larger active surface and caking or fluxing less readily when heated.

The manufacture of hydrogen by this process proceeds in alternating period, in one of which oxidized iron is converted by a cheap reducing gas to spongy iron, and in the other period steam is passed over the spongy iron with liberation of hydrogen. The cycle of operations proceeds continuously.

The essentials for the process are, therefore, iron ore, reducing gas and steam. Water gas is used as the reducing gas, and thus the plant required consists of a water gas installation and a special hydrogen apparatus.

The decomposition of the steam by the incandescent iron is effected in vertical iron retorts set in furnaces heated by producer gas. The retorts are charged with iron ore through the upper lids. Above the retorts are valves for regulating the passage through the retorts of steam and of reducing gas alternately and for taking off the hydrogen and the spent reducing gases. The latter, consisting chiefly of carbonic acid and steam, are either discharged into the open, through a shaft or are passed in to the retort furnaces, where any unconsumed constituents are utilized in heating the retorts.

The hydrogen gas thus produced passes from the retorts to the purifying plant. The first section of the latter is a condenser packed with coke sprinkled with water. From this condenser the hydrogen goes into two purifying vessels, worked in series, for the extraction of sulphur and carbonic acid. The gas then passes to a gasholder, from which it can be taken either for immediate use or to a compressing station, where it is filled into cylinders. The hydrogen finally obtained by this process has a specific gravity of $0.090=0.092$; its purity is 97 to 98 per cent, the residue consisting of nitrogen, with 0.2 to 0.3 per cent carbonic oxide; furthermore, since the gas was cooled by contact with water it is saturated with water vapor.

A plant for producing 3500 cu. ft. per hour requires four workmen for each shift. Skilled labor is not essential. The iron ore which is used in the process can be kept in the retorts in uninterrupted operation for about two or three months. For efficient service the plant must be worked continuously, since it requires fourteen to twenty-four hours to start up from the cold.

THE RIKER-WOLTER PROCESS—A CHEMICAL PROCESS FOR THE DECARBURATION OF OIL.

This process is the result of a research which originally aimed at the production of an illuminating gas, but failing in this a highly efficient hydrogen-producing process which is now being used to a great extent by the iron-steam and the contact process. It is this process which is now being used to a great extent by Germany and Russia in their aeronautical work owing

to the portability of the apparatus. Complete installations are set up on railway cars and carried from point to point as required. The plant takes up but little space, and is more easily supervised than the two other processes described above.

The process is one in which gas oil is used which is heated to 1200 to 1400 deg. C. and decomposed into its chief constituents, carbon and hydrogen. The plant comprises the special gas-making plant and purifiers. The gas-making plant consists of two producers which are charged with coke. There is a gas connection from the lower part of the first to the upper part of the second producer; near the furnace and clinking doors of the producers are air inlets. These air inlets are fitted with valves having interlocking gears to prevent accidents arising from careless manipulation. The air required to raise the heats in the producers is forced through these inlets by a high-pressure blower.

When the producers have reached the requisite temperature, the blower is stopped and the blast valves closed. Oil is then pumped onto the coke in the first producer, through spraying nozzles which atomize it. It is converted into vapor by the hot coke and passes through the bed of hot coke in the second producer. In this way the vapor is converted into a permanent gas, which leaves the bottom of the second producer and enters a hydraulic main. When the air is in turn again blown in at the base of the producers in order to raise their temperature, the carbonaceous residue left by the oil on the coke is burnt and contributes towards the heating up of the producers. It requires one to one and a half minutes' blast to raise the producers to the proper temperature again. Thereupon oil is again introduced into the first producer.

The oil is preheated in order to render it sufficiently thin and mobile to pass through the spraying nozzle. For preheating the oil the exhaust steam from the turbine or engine used for driving the blower is utilized. Solid impurities are removed from the oil by pumping it from the storage tank through a filtering chamber.

The gas issuing from the second producer passes through a water seal in the hydraulic main, and there deposits the greater part of the sooty matter which is carried over mechanically. Clean water flows continuously into the hydraulic main, and the sooty water flows off and runs into a settling pit, having partitions which force the water to take a long and tortuous course in order to ensure the deposition of the solid matter.

The last two chambers of the settling pit are packed with coke, which acts as a filter and retains the last traces of impurities, so that the water may be run thence direct into any sewer or river. Soot is the only by-product of this process; the oil contains 80-85 per cent of carbon, of which the greater part is liberated; only a small proportion of carbon is found in the form of hydrocarbons and carbonic oxide in the crude hydrogen gas. Most of the liberated carbon is retained by the coke in the producers, and is later burnt by the air blast. A small proportion goes forward as soot in the gas, and is deposited in the hydraulic main and washer. The soot which collects in the settling pit when dried can be burnt under the boiler. The gas passes from the hydraulic main into a washer, where sprays of water remove the last traces of soot.

On leaving the washer the gas contains 6 to 8 per cent of carbonic oxide and sulphuretted hydrogen. The latter is removed in a purifier charged with bog iron ore. The carbonic oxide is extracted by hot soda-lime in the following manner: The gas passes from the iron oxide purifier into thin-walled retorts, set in a furnace which keeps the soda-lime with which the retorts are charged at a temperature of about 300 deg. C. At this

temperature the soda-lime absorbs the carbonic oxide from the gas. The gas thus purified is cooled by passage through an atmospheric condenser and is then stored in a gasholder. The purity of the gas is from 97 to 98 per cent, the residue being nitrogen. The specific gravity is 0.087 to 0.090.

The operation of the plant is not difficult, and requires only moderate supervision. The producers can be heated up for use in one to two hours, and can be operated continuously for a few hours at a time or for days, weeks or even months.

An installation of this type may be either stationary or portable. The layout of a portable installation of this process, as now used by the governments of Germany and Russia, is as follows: The producers, with oil tank, oil pump, pre-heater and hydraulic main, are installed on one railway truck, and the purifying plant, including the washer and the final condenser, is arranged on a second truck. A gas holder constructed of balloon-fabric is carried on a third truck. The gas then passes from this holder to a compressor, placed on a fourth truck, by which it is compressed into steel cylinders.

PRODUCTION OF HYDROGEN BY ELECTROLYSIS.

In this process water is decomposed into its constituent elements, oxygen and hydrogen, by the aid of the electric current. One of the first commercial plants of this type to be erected in the United States was at Waverly, Newark, N. J., in 1911. The electrolytic generators, or cells, are of two types; the unit type is composed of an outer tank, which serves as the negative electrode, and a perforated inner tank made of special composition iron which serves as the positive electrode. The two electrodes are separated by means of a specially prepared asbestos diaphragm which divides the apparatus into two compartments. On top of the cover are the current terminals, two sight feed indicators and pressure equalizers, also a cup through which water is introduced into the cell from time to time.

As soon as the electric current is applied oxygen and hydrogen are seen to bubble through the indicators. The electrolyte is an aqueous solution of caustic potash or soda, which serves to make the water a good electrical conductor. In each cell about 1 gal. of water is decomposed per 24-hr. day, producing 76.8 cu. ft. of oxygen and 153.6 cu. ft. of hydrogen. The hydrogen is liberated on the walls of the outer tank (negative electrode), while the oxygen forms on the walls of the inner tank (positive electrode). The oxygen is carried up through suitable means to the oxygen equalizer, where it bubbles through water and passes on to the oxygen off-take pipe; the hydrogen similarly passes through the hydrogen equalizer and thence to the hydrogen off-take pipe. Each cell produces per kilowatt hour, 8 cu. ft. of hydrogen and 4 cu. ft. of oxygen. The current required per cell is 400 amp. at 2 volts. The purity of the electrolytic hydrogen is 99.8 per cent and the oxygen 99.6 per cent.

The cost of hydrogen by this process, disregarding the value of the evolved oxygen, is about $\frac{1}{8}$ of a cent per cubic foot at a current cost of 1c. per kw.-hr. at the generator. For small or moderate size plants where low cost current is available the electrolytic process is preferable to any other for the production of hydrogen.

The attractive features of this process are: (1) the simplicity of operation; (2) the little attention required (not exceeding the cost of a few hours of one man's time per day); (3) cheap raw material (requires only 1 gal. of water to be added to each cell per day). The plant can be operated continuously for years without cleaning or overhauling; the process is clean and

safe, and the cell produces gas as soon as the current is turned on.

Another variation of the unit type generator or cell is the bipolar generator recently placed upon the market.[†] This type of generator is of the filter press type, but is not a modified filter press. While the form of this generator was early introduced in the art the bipolar type only resembles same in form. It is specifically designed for the electrolytic separation of water at the highest efficiency. This type of generator is to be commended where floor space is a consideration, as it is more compact than the unit type cell. The bipolar generator is made in two sizes. The 4 x 11 ft. has a rated daily capacity of 1700 cu. ft. of hydrogen and 850 cu. ft. of oxygen. Size 5 x 15 ft. has a rated 24-hr. capacity of 700 cu. ft. of hydrogen and 3500 cu. ft. of oxygen. The above capacities are based on the use of caustic potash as electrolyte. Purity of the hydrogen is 99.8 per cent and oxygen 99.6 per cent. The generator may be operated twenty-four hours a day and 365 days in the year. The cost of the gases produced is about the same as in the unit type. The bipolar generator is as completely automatic as a high duty generator of this type can be made. Practically the only attention required in operation is in the maintenance of the water supply. Only part of one man's time is necessary.

Hydrogen in the Industries

HYDROGEN EMPLOYMENT IN QUARTZ GLASS.

Quartz glass, which has long been recognized as an important material in the manufacture of various articles employed in the chemical industry, was first produced in 1839 by Prof. Gaudin. Some of his quartz tubes and elastic threads were exhibited at the Paris Exposition in 1878.

In 1889, Boys, who recognized the possibilities of this remarkable substance, also succeeded in making small tubes and other articles.

However, little progress was made in the development of the quartz-glass industry until 1900, when Heraeus and Achendstone succeeded in making clear rock crystal articles large enough for practical purposes. The raw material is washed quartz sand containing 95 per cent silicic acid, which is melted by the oxy-hydrogen flames, and it is now possible to melt and to mold into almost any desired form as much as 50 lb. of quartz at a time.

One of the remarkable properties of the quartz glass produced by this process is its resistance to acids. Even boiling acids, with the exception of hydrofluoric and phosphoric, will not readily affect it. Quartz has the advantage of having a very low co-efficient of expansion, being about 1/17 that of the best glass suitable for chemical utensils and apparatus. The manufacture of quartz glass in the United States is only of very recent date.

HYDROGEN IN BALLOONS AND DIRIGIBLE AIRSHIPS.*

Hydrogen, on account of its very low density, has the greatest lifting power of all gases, and is therefore used for filling balloons. The amount which a balloon will carry up, i.e. "its ascensional power," is the difference between the weight of the balloon itself with its contained hydrogen, and that of an equal volume of air. A liter of hydrogen gas has an ascensional force of 1.2 grams. The specific gravity of 98 per cent hydrogen is 0.087, which corresponds to a lifting power of 73.5 lb. per 1000 cu. ft. Pure hydrogen has a specific

gravity of 0.07, which corresponds to a lifting power of 75 lb. per 1000 cu. ft.

Hydrogen for balloon purposes must be free from impurities that would injure the fabric, and should be dry. It is not necessary that the hydrogen be under pressure for inflating a balloon. It will readily inflate at atmospheric pressure.

MELTING OF PLATINUM.

In the melting of platinum the oxy-hydrogen burner is used exclusively. The temperature of the oxy-hydrogen is about 2100 deg. C., whereas the melting point of platinum is 1755 deg. C. The great advantage of this flame is that it contains no elements injurious to the platinum such as carbon. Illuminating gas, which was formerly used instead of hydrogen, was detrimental to platinum. The operation is carried out by passing oxygen and hydrogen at high pressure through an especially constructed oxy-hydrogen torch. The author devised a torch for this work several years ago, and it is practically the only platinum melting torch (oxy-hydrogen) used to-day in the United States by platinum smelters. The melting is best accomplished in a lime crucible. Oxygen and hydrogen at a pressure of 1800 lb. per square inch in cylinders containing 100 and 200 cu. ft. with reducing valves and regulators are used.

PRODUCTION OF THE SYNTHETIC RUBY AND SAPPHIRE.

Practically all of the beautiful minerals of the corundum family are now being produced synthetically. The ruby and sapphire are the more important.

Alumina being the base of those precious stones, it remains only for the chemist to add the proper oxide to obtain the required colors and to fuse them together in the oxy-hydrogen flame. The ruby, for example, contains 98 per cent of pure alumina and about 2 per cent of chromic oxide.

The materials used are of the purest. It is absolutely essential that the material be pure, as otherwise the product obtained will be faulty and the color will be poor.

At a temperature of 1000 deg. C, the material is calcined in a large oven and removed and reduced to a fine powder. The fine powder is then placed in the magazine of the oxy-hydrogen burner and forced down on a receiving base below the flame. The work at this stage is very delicate and requires most careful attention. All conditions must be regulated with mathematical precision, the rate of flow of the Al_2O_3 powder, the rate and pressure of the gases and the quality of the flame (1900 deg. C.). With conditions properly adjusted the stone at first appears as a little stalk not larger than a pin head, which gradually grows in the fire. This stalk, as it grows taller, is broadened out by the manipulation of the torch by a skilled operator so as to form a small cone with the point down. The desired size obtained, the operator shuts off the gases and allows the jewel to cool. It is then broken from the base and is ready for cutting.

Electrolytic oxygen and hydrogen are used exclusively in this industry on account of the exceedingly high degree of purity of the electrolytic gases.

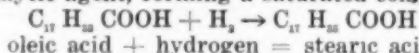
HYDROGENATION OF OILS.

In connection with the fat industry a very extensive use for hydrogen has developed. By the introduction of hydrogen into fatty bodies and oils of low melting point these are converted into hard fats of higher melting point. In other words, oils which are composed of unsaturated acids, such as oleic acid and their esters,

[†]See MET. & CHEM. ENG'ING, Vol. 14, p. 108.

*Cf. Ardery, MET. & CHEM. ENG'ING, Vol. 14, p. 333.

will combine with hydrogen in the presence of a suitable catalytic agent, forming a saturated compound:



The hard fats have a greater market value for the manufacturer of soap, candles and oleomargarine. Fish oils, etc., lose their disagreeable odor in the hardening process. The application of hydrogen in the fat industry has brought about a great advancement. The process worked out on the following lines is known as hydrogenation.

The addition of the hydrogen to the unsaturated hydrocarbon of the soft fats is accomplished by exposing the latter to hydrogen under pressure at high temperature in the presence of a contact agent such as a mixture of finely divided clay with metallic nickel, copper or iron. This mixture is sprayed into a container made of boiler plate under a pressure of 4 or more atmospheres, the pressure varying according to the method of working and the catalytic agent employed. Into the container from the opposite end is introduced a current of hydrogen, which at a temperature of about 150 deg. C. readily combines with the oil or reduces the fatty acids. The hydrogen is added in excess in order to facilitate the conversion, but the surplus hydrogen, after being freed from oil particles, is returned to the storage tank.

The consumption of hydrogen varies according to the nature of the raw material and the hardness of the product. It is usually from 2870 to 4300 cu. ft. per ton. The fatty product run-off from the pressure vessel is an emulsion of the fat with the contact substance. The latter, after separation by centrifuging, is used over again.

The contact substance, according to the patent of Leprince and Siececke (Dr. Norman) is finely divided nickel or copper; according to Fokin, it is platinum, and according to Paal, palladium. With the last two conversion is effected at ordinary or relatively low temperature and at an exceedingly low pressure. Wherever these two rare metals in suitable form are used, many improvements in the process have lately been introduced. It is absolutely necessary to use hydrogen of a high degree of purity, since slight impurities in the gas will render the contact substance inactive. In the hydrogenation of cotton seed oil, 1 per cent of hydrogen by weight converts it into a fatty body of the consistency of lard. The product obtained is edible.

THE SYNTHETIC PRODUCTION OF AMMONIA.

The discovery of the synthetic production of ammonia by Professor Haber of Karlsruhe a few years ago promises a very extensive use for hydrogen. It is of immense importance because it forms the basis of the well-known fertilizer, sulphate ammonia. When hydrogen and nitrogen are heated to 200 deg. C. in their combining proportions, under high pressure and in the presence of uranium as a contact substance, they unite to form ammonia. About 6 per cent of ammonia is produced, and by removing this a further conversion is effected. The yield can undoubtedly be greatly increased and the process accelerated by the selection of a possibly more suitable contact substance and the application of possibly more appropriate temperature and pressure.

A Proposed Quick Analytical Method for Determining the Zinc in Retort Residues or Electric Zinc Furnace Slags

BY WOOLSEY MCA. JOHNSON

The method indicated by the above title was devised by me in 1904 when running the No. 2 Plant of the

Lanyon Zinc Co., at Iola, Kansas. It was tried out in a preliminary way at the La Harpe electric furnace laboratory but never perfected. It is thought that it has been perfected on the drawing-board and it should work all right, although changes will be found necessary when apparatus and method are tried.

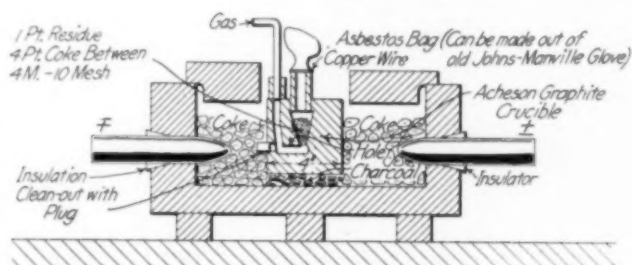
Briefly described the apparatus is similar to the 20-kw. test electric crucible furnace working at 15 to 45 volts, such as I developed in 1903, made of No. 8 sheet steel with riveted 2-in. angle bars on corners and 3-in. electrode. It can be made of one course of magnesia or of one course of magnesia and one course of firebrick or Armstrong nonpareil insulating brick.

In it is placed a machined 4-in. Acheson graphite electrode with a centered conical hole at the bottom of which enters a 1/2-in. hole. Through the latter a stream of gas flows upward.

The gas is led in by a vertical hole, connecting with an iron pipe to gas supply.

In the center of the tester is placed a mixture of 1 part residues, 4 parts coke, the latter sized between 10-mesh and 4-mesh.

Into the working space of the crucible is screwed an



APPARATUS FOR DETERMINING ZINC

Acheson graphite plug on the top of which is a hood of asbestos cloth. The purpose of this last-mentioned is to catch the zinc dust.

When the apparatus is set up and a weighed amount of residue in the tester, the temperature is quickly raised to 1600 deg. C. and a good flow of gas maintained. At this temperature, the zinc is all reduced because reductivity both in gaseous and solid phase is tremendous. The fume is caught in the bag as high metallic blue-powder with nearly all the lead.

It only remains to cool the bag down carefully and dissolve the zinc in acid so dilute that asbestos is not affected. The solution after a sulphate is added is then ready for the usual titration, as it is now pure $ZnSO_4$. As an alternative, the zinc vapor can be caught on glass-wool in a suitable small dust-collector, which is preferable but not worked out to my satisfaction in my own mind.

The zinc may also be determined by measuring the hydrogen evolved under proper conditions as would occur to the mind of any technical chemist.

In case of electric zinc furnace slag, it must be ground very fine and mixed with a larger amount of coke. My preferred course of treatment would be to take a large amount of the material (10 to 40 grams) to be analyzed, taking a fraction of same for the final determination. There is no reason why the entire determination cannot be made in 15 minutes. It would be much more accurate than the usual method which leaves some zinc undissolved. A battery of crucibles or a 4-in. x 4-in. x 24-in. electrode with a plurality of holes with perforated graphite or "alundum baskets" could be used in the works laboratory.

If power were cheap and plentiful, I have no doubt that it could be developed into a very satisfactory technical method.

Recent Chemical and Metallurgical Patents

Iron and Steel

Agglomerating Fine Ore.—A process and device for agglomerating or sintering flue-dust or fine ore is illustrated in Fig. 1, being the patented invention of PHILIP O. HARDING of Pittsburgh, Pa. The feature of the invention consists in submitting the material to be treated to a progressive combustion, and in providing a flow of air to support combustion in a direction counter to

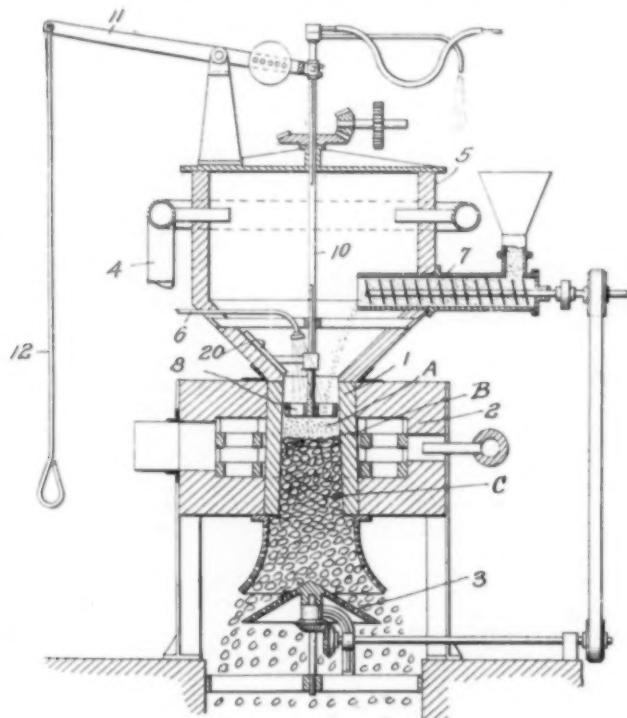


FIG. 1—AGGLOMERATING MACHINE

the flow of material. This counter-current flow of air serves to sweep any unsintered particles back into the zone of combustion for further treatment. The sintering chamber 1 is of tubular form, surrounded by an annular reverberatory chamber 2 from which the supply of heat comes. Air for the support of combustion is drawn upward through the body of material into an exhausting chamber 5 from which the air is drawn through a pipe 4. The material to be sintered is introduced by screw 7 and is distributed and leveled by the spreader and pusher 8. Discharge is effected by the revolving cone 3 which to a certain extent disintegrates the sinter cake, exposing any friable or untreated material to the current of air which carries it back into the fire zone. (1,166,903-4, Jan. 4, 1916.)

Recovering Flue-Dust.—A method of preparing flue-dust for further reduction in the blast-furnace is disclosed in a patent granted to SAMUEL W. OSGOOD, Chicago, Ill. He proposes to mix the flue-dust with water and perhaps a suitable binder, such as lime or coal-tar, and form pellets of desired size. In order to reduce the iron oxide contained in the flue-dust to metallic iron, he utilizes the heat and reducing gases of the blast-furnace slag by introducing the pellets into the molten slag as it leaves the furnace. By subsequently granulating the slag, the iron pellets can be recovered by screening, gravity separation or magnetic separation. (1,166,927, Jan. 4, 1916.)

Washing Blast-Furnace Gases.—The application of the counter-current principle to the washing of furnace gas, and the conduct of the operation in three

stages form the basis of the patented process of HERMANN A. BRASSERT of Chicago, Ill. The first stage consists in thoroughly wetting every part of the gas, using the counter-current principle so that the hot, dirty gas encounters first the warm, dust-laden discharge water; the washed gas encountering the cold water entering where the gas leaves. This removes the greater portion of the solids; and in the second stage the finely divided matter is removed in similar manner by subdividing the streams of gas and water more finely and introducing baffles. In these two stages of washing every drop of water is used over and over, being retarded and arrested as often as possible until it has taken up the maximum charge of dust. The third stage consists in drying the gas, and in this stage it is desirable to reverse the conditions in the first two stages, viz., by removing water as quickly as possible from the path of the gas.

Apparatus for the first two stages consists of a vertical cylindrical tower. For the first stage the tower contains a series of trays. The second stage is arranged immediately above these trays and consists of wooden slats arranged at different angles to the flow of gas so that the direction of flow is changed between each set of slats. For the third stage a cylindrical casing is provided, into which the gas enters in a horizontal direction

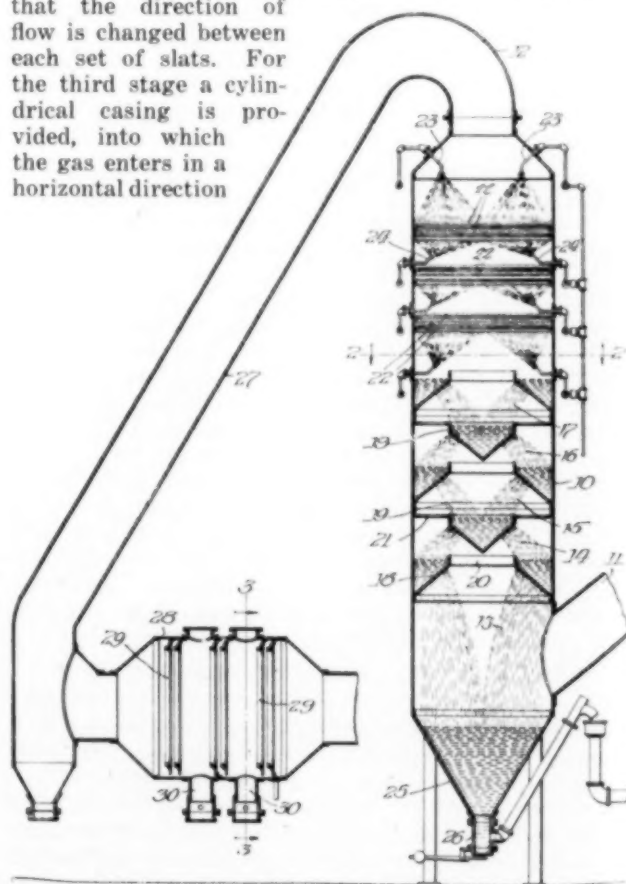


FIG. 2—GAS WASHER

and flows through sets of vertical wooden baffles, on which the water entrained in the gas collects and trickles downward out of the path of the gas. This water is finally collected in receptacles at the bottom of the drying chamber. The construction of the gas washer is shown in Fig. 2. (1,169,764-5-6, Feb. 1, 1916.)

Gold and Silver

Cyaniding Under Pressure.—In apparatus for cyaniding, patented by Mr. BRUNO KOERING of Detroit, Mich., all of the processes of agitation, filtering and washing are conducted in a single revoluble filter drum.

In case the ore is originally ground in water, the pulp is first dewatered in the drum before cyanide solution is added. After the ground ore and solution are thoroughly mixed in the drum, air or steam is introduced to bring the pressure up to from 15 to 60 lb. per square inch, and the drum is then slowly revolved for two to eight hours, according to requirements. The solution is then displaced through the filter lining and the pulp is washed with barren solution or water, after which it is discharged. The original cyanide solution may be heated, or heat may be supplied from steam introduced under pressure.

Slime Filter.—A type of vacuum filter, in which the operation of filtering takes place in a horizontal frame and the cake is discharged by tipping the filter to an inclined or vertical position, is patented by Mr. CHARLES BUTTERS of Oakland, Cal. The cake is formed by flowing a stream of pulp onto the filtering medium until a cake of desired thickness has been formed. After forming the cake and removing the valuable liquid, a wash solution may be directed over the cake for the purpose of displacing any valuable solution that may remain with the solids. After the cake is washed it is discharged by tilting the horizontal frame to an inclined or vertical position. Any number of filter units can be combined in a suitable frame. An earlier reference to this filter was made in this journal, April, 1914, giving illustrations of the apparatus in various positions. (1,165,068, Dec. 21, 1915.)

Copper

Method of Smelting Finely Divided Ores.—Finely divided ores are not suitable for smelting in the blast-furnace on account of the readiness with which they are carried out by the blast, and they are difficult to smelt in reverberatory furnaces by reason of their tendency to pack and prevent reaction gases from gaining access to the individual particles. In order to obviate these difficulties in smelting finely divided ore, Messrs. JOHN H. KLEPINGER, MILO W. KREJCI and CHARLES R. KUZELL, of the Anaconda company's staff, at Great Falls, Mont., have patented an improved process of smelting such ores. The object is to so handle the ore that each particle will be surrounded, as it enters the furnace chamber, by the heating medium and reaction gases. The process may be either oxidizing or reducing, according to the nature of the ore and the desired result, but in any event the object sought is to envelope each particle of ore with a gaseous film, thereby insuring the smelting of the ore in a minimum of time and in the most economical manner. For this reason provision is made to feed the charge in the form of a spray or cloud.

The process applied to the reduction of oxidized ores is illustrated in plan in Fig. 3, and may be explained with relation to oxidized ores of copper which are reducible by reaction with a reducing agent. Referring to the figure, 1 represents an inclined revoluble smelting cylinder which is a combined combustion, treatment and reduction chamber; 4 is a two-compartment hopper from which the materials, ore and fuel, are fed by

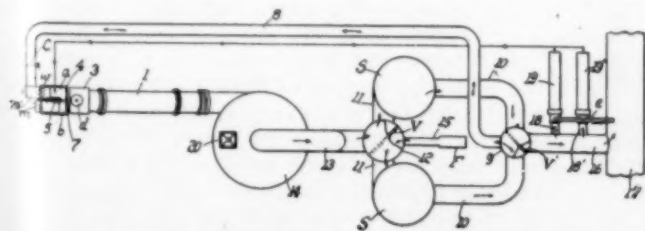


FIG. 3—SMELTING FINELY DIVIDED OXIDE ORES

screws to an air-nozzle beneath and thence into the igniting chamber 3 and upper end of cylinder 1. A settling chamber 14 is provided as a receptacle for the smelted product, from which slag and metal can be withdrawn from tap-holes. The waste hot gases pass from the settling chamber through one of the preheating stoves *S*, *S*; and at the same time air is forced through the other by fan *F*. Suitable reversing valves *V* and *V'* permit the alternate heating of one stove by the waste gases while the other is preheating air for the smelting operation. After leaving the stove, the hot waste gases pass on to driers 19 and 19', containing the ore and fuel charge, respectively, and from which the dried charges are conveyed to their hoppers *a* and *b*. Before commencing smelting operations, the combustion and settling chambers and stoves are brought to the proper temperature by burning a certain quantity of powdered fuel, after which ore may be introduced. The reduction of the metallic oxides and the fusion of the resulting metal are accomplished in the chamber 3 and cylinder 1 while the particles are still in suspension, the atmosphere in the apparatus being kept in a highly reducing condition. The products of smelting flow down the cylinder into the settler 14. (1,160,621, Nov. 16, 1915.)

The same principles may be applied to the smelting of finely divided sulphide ores or concentrates, such as result from the flotation process. In this case the re-

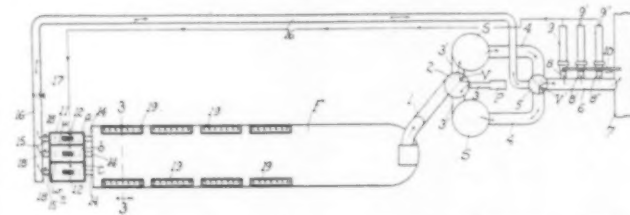


FIG. 4—SMELTING FINELY DIVIDED SULPHIDE ORES

action is oxidizing in character, and the fuel may be derived wholly or partly from the ore itself through the oxidation of such constituents as sulphur, iron, arsenic, etc. In the case of copper ores the product is a matte. This process is illustrated diagrammatically in plan in Fig. 4, in which the heat-regenerating apparatus is shown in connection with a reverberatory furnace. The ore, flux, and fuel when necessary, are dried in driers as above described and delivered to screw-feed hoppers *a*, *b* and *c*, from which they are blown into the furnace by means of air preheated to a temperature of about 1000 deg. Fahr. in the stoves *S*, *S*. The charge being delivered into the furnace in the form of a spray or cloud, each particle of ore is surrounded by the heating and oxidizing medium and is fused or smelted in suspension. Over-oxidation may be corrected by introducing coarse raw ore into the furnace through the side hoppers 19. The process eliminates the preliminary step of roasting that is necessary in the former methods of smelting. (1,164,653, Dec. 21, 1915.)

Ozone

Ozone Generator.—An ozone generator designed to prevent short-circuiting of the apparatus by moisture and to provide a simplified construction and new arrangement of the cooling system is patented by WILLIAM O. FREET of Hackensack, N. J. (assigned to Steynis Ozone Co. of New York). In this generator short-circuiting by moisture is prevented by inclosing the entire apparatus in an air-tight box, and placing a drying element in the box. The drying element contains calcium chloride or some other suitable absorber of moisture. Another feature which prevents short-

circuiting by moisture is the admitting of the air between two concentric electrodes instead of outside the electrodes. A cross-section of the generator is shown in Fig. 5. The outside casing 1 contains two separate ozonizing elements as shown. The inside electrode 8 is made with a spiral groove to provide large discharge space. The outside electrode 19 is a concentric tube inclosing dielectric 12, inside electrode 8, and cooling pipes 9 and 10. The air enters at 14, passes down through ozonizer between inside electrode 8, and dielectric 12, where the discharge takes place and ozone is formed. It then passes out through opening 6 and up

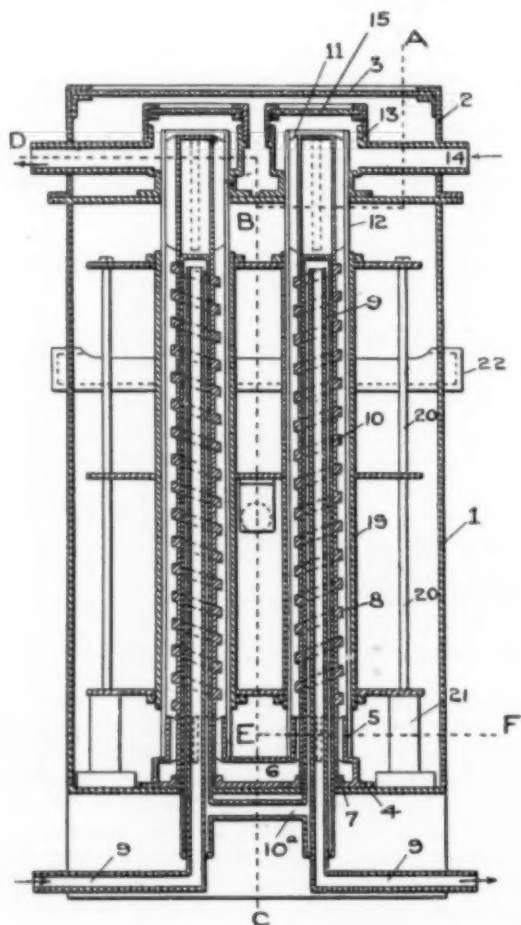


FIG. 5—OZONE GENERATOR

through the other ozonizing element and thence out of the apparatus. The cooling medium, ammonia brine or other suitable substance, passes in through left-hand pipe 9 in the opposite direction to the flow of air so that the hottest air or ozone will come in contact with the cooling fluid first. The cooling fluid passes up through pipe 9 out over its top, down between pipes 9 and 10 into direct contact with the electrode. The cooling fluid passes down and through passage 10a and thence to the right hand ozonizing element. The drying element is shown at 21. (1,157,859, Oct. 26, 1914.)

Process of Producing Ozone.—A process and apparatus for producing ozone is patented by JAN STEYNIS of Bay Shore, N. Y. The operation of the process is as follows: An ammonia compressor delivers compressed ammonia to cooling coils where it is condensed to a liquid. The liquid ammonia is then conducted to a coil of pipe in a chamber used for drying and cooling the air. In this latter coil the ammonia becomes gasified again. From the drying chamber the ammonia gas now goes to the jackets of the cylinders of the ozone generator where it cools the air as it passes through the

generator. From here the ammonia is conducted back to the compressor.

Following the course of the air it is first compressed in an air compressor. It then passes to the drying and cooling chamber through which the above mentioned ammonia cooling pipes pass. From here the air passes to the ozone generator which may be of any approved type. The type preferred, however, is one in which the air in passing through the generator is subjected to the cooling action of the cooling medium and to electrical discharges successively.

The cooling medium flows in a closed circuit, and by first causing it to pass through the drier and then through the generator, the temperature in the generator will be slightly higher than in the dryer, which insures against moisture being precipitated from the air in the generator which would seriously interfere with the generator. It is also claimed that with this system an even temperature may be maintained in the ozonizer. (1,162,415, Nov. 30, 1915.)

Synopsis of Recent Chemical and Metallurgical Literature

Slime Settlement

Determining the Capacity of Slime Settling Tanks.

—In an elaborate paper contributed to the *Transactions of the American Institute of Mining Engineers*, H. S. COE and G. H. CLEVINGER present preliminary results of a laboratory method for determining the capacities of slime-settling tanks. The general phenomena of settling were studied by observing the action of thin pulps in glass cylinders, and defining four zones into which the pulp separated during the process of settling. As a result of this study the authors derive the

$$62.35R$$

formula $C = \frac{62.35R}{F - D}$, where 62.35 = weight of 1 cu. ft.

of water.

F = ratio of fluid to ore in the pulp tested.

R = rate of settling in feet per hour of a free-settling pulp of consistency F .

D = ratio of fluid to solids in the discharge required.

C = capacity in pounds of solids per square foot per hour, which may be discharged with a consistency of D from a layer of pulp of a consistency of F settling at a rate R .

The results of the investigations are summarized as follows:

1. In thickening pulps which are to be discharged at a consistency such that the discharge is still in the form of free-settling pulp, the depth of the tank used is of no consequence, except in so far as it permits a depth of feed sufficient to avoid surface agitation and allows ample depth of clear liquid to care for fluctuations of the feed and changes in the character of the pulp in the case of continuous thickeners, and sufficient depth to give ample capacity to avoid the necessity of frequent charging and discharging in the case of intermittent thickeners.

2. When thickening pulps to a consistency where it is necessary to expel fluid by compression, sufficient capacity must be given the tank so that the pulp will be retained the necessary period of time to thicken it to the required density and also to allow sufficient storage to compensate for fluctuations in the feed and discharge. This capacity may be obtained by varying either the depth or diameter to give the required cubical content.

3. The consistency of discharge possible may be closely determined by allowing a cylinder of thick but free-settling pulp to settle, taking readings at intervals of a

few hours up to the point where settling practically ceases.

4. The required area may be computed by applying the formula

$$A = \frac{2000}{24 \left(\frac{62.35R}{F-D} \right)} \quad A \text{ is the area in square feet}$$

required to thicken 1 ton of 2000 lb. of solids to a consistency in the discharge of D (parts fluid to 1 part solids by weight), per day of 24 hr. A series of settling rates is taken on pulps ranging in consistencies from that of the proposed feed to the thickest free-settling pulp. D is taken as the ratio of fluid to solids in the thickest pulp which can be economically obtained. The greatest value for A indicated by the tests is taken as the required area. Under ordinary circumstances a factor of safety should be allowed over the calculated area to take care of changes in the character of the pulp and variations in temperature. It will be noted that this is the same formula previously given, modified to give area required instead of capacity per square foot-per hour.

5. The required depth of the thickener may be ascertained by computing the capacity of the thickening zone to contain a supply of solids equal to the total capacity of the tank for the number of hours required to thicken the pulp to the density required in the discharge, and to this depth adding an allowance for the lost space due to the pitch of the drag in the thickener; also from $1\frac{1}{2}$ to $2\frac{1}{2}$ ft. for depth of feed and a further allowance for storage capacity when the discharge may be closed. The following is an illustration of the method used in computing the area and depth required in a thickener to handle 100 tons of pulp per day, thickening from 6 parts fluid to 1 part solids down to 1.12 parts fluid to 1 part solids.

The authors define in detail their method of making settling tests, and give a description of special apparatus for small-scale work. A number of tests are tabulated on slime from representative mills in different parts of the country.

Concentration

Glass Surfaces for Ore-Dressing.—The use of glass surfaces for ore concentration is attracting considerable attention in Cornwall, and numerous tests have been made which indicate the possibility of improving the present practice. Mr. W. H. TREWARTHA-JAMES writes on the subject in the February *Mining Magazine*. It is claimed that better results are obtained in dressing slime, and even coarser pulp, by the use of fluted and frosted glass surfaces. Frosted surfaces can be graded as required by treating the glass with sand of a definite size by the sand-blast machine. Fluted surfaces also are frosted in a similar manner, and the depth and shape of the flutes graded. The author describes fluted surfaces on glass $\frac{3}{16}$ in. thick, containing sixteen flutes per linear inch, with the depth of riffle $\frac{1}{16}$ in. The selection of suitable surfaces is based partly on microscopic measurement of the particles, and upon sizing and grading the particles by elutriation, confirmed by tentative tests of standard gradings on a fixed inclined surface.

The function of the frosting, pitting and fluting of the glass surface seems to be to produce proportionate retardation of that part of the pulp stream with which the glass surfaces are in contact. So far as known, these surfaces have been applied to two forms of plant: the Cornish 18-ft. round revolving frame and the Cornish fixed inclined frame. The surfaces are exceedingly sensitive to variations in the mechanical and physical conditions of the pulp, which is a practical point that

has to be translated into full-scale work before a decisive demonstration can be given. The following factors seem to be worthy of consideration:

1. The selection of a suitable glass surface, or series of surfaces, adapted to deal with uniform types of pulp which must not vary between certain limitations as to sizes of particles, pulp dilution, and the relative percentage of mineral contained.

2. The adaptation of the slope of the surface with regard to the degree of dilution of the pulp; that is, the proportion of dry pulp to water, and the other conditions mentioned.

In a further discussion of the subject, Mr. W. MORLEY MARTIN, the inventor, speaks as follows:

"Heresy though it may be, the results obtainable incline one to think that the function of specific gravity as generally understood in ore-dressing can be considered in a slightly different way and that surface retardation is, in reality, not a minor factor but the most important of all. Such retardation when properly applied appears to be proportional to the varying specific gravities of the component constituents of the solid particles in any given pulp. In other words, when scientifically applied, the difference in the rate of travel between varying specific gravities is attained with consequent separation. Obstruction of surface is not retardation: the former obstructs the whole, the latter retarding in a given order."

Mr. Martin gives the results of some tests using the same pulp on different glass surfaces, and shows the wide variation in products obtained, from which he concludes: "According to surface conditions, so are the results, and two or possibly three different surfaces on the same table may be necessary. Surely, then, if surface is paramount, to get such surface under control so as to obtain what is desired must be advantageous and superior to a chance surface with unalterable capacity and grade of product producible therefrom. The one can be made to do what you want it to do, and the other cannot."

An improvement in flotation by the agitation-froth process is published by Mr. FRED WALSH in the *Australian Mining Standard* for Feb. 3. He states that colloidal gangue matter in a pulp is frequently a serious impediment to the successful concentration of the fine sulphides, and where the proportion is very high it has prevented profitable treatment by flotation. Apparently the colloidal matter in suspension renders ineffective the frothing agents. In order to overcome this difficulty he proposes to add to the pulp a small quantity of an electrolyte of low dissociation constant, such as a weak organic acid or other weak hydrion-producing electrolyte, or salts of weak organic acids, such as crude acid potassium tartrate. Tartaric or citric acid also are claimed to produce the desired effect. The electrolyte must be such as to cause no precipitation of the colloids in such a way as to coagulate mineral slime with gangue slime. Where sulphuric acid is used in the flotation process the electrolyte may be introduced before that acid, as, for example, at the grinding stage in the preparation of the pulp. Such an electrolyte, however, may be effectively employed where sulphuric acid is not used, and with or without the employment of oil or any other agent.

Old Barytes Plant Reopened.—The Virginia Zinc and Chemical Co. will begin operation shortly of the old barytes plant near Bristol, Tenn. This plant was closed in September, 1909.

The Electro Bleaching Gas Co. manufacturers of liquid chlorine announce the removal of their general offices to 18 East Forty-first Street, New York.

"Multiple Filtration" Filter and Grease Extractor

Filtration of the boiler feed water is practically a necessity in all modern, economically operated boiler plants, and more especially in plants where the hot condensate returns from the condenser and heating system is used in making up the boiler feed. Filtration removes the finally divided solids contained in the feed water, but its most important function is the extraction of the oil and greases carried over from the main engine cylinders and auxiliaries by the exhaust returns. Oil and grease, as is well known, are the most detrimental substances that can be injected into a boiler, both for efficiency and safe operation.

Effective extraction of oil and greases from water is realized only by means of successive filtration through a series of filters, each of ample capacity to permit the comparatively slow percolation of the water through the grease absorbing and extracting medium. To secure such successive or multiple filtration in a filter occupying comparatively small space, the Lagonda Manufacturing Company of Springfield, Ohio, has developed a filter and grease extractor in which the filtering medium consists of a long strip of Terry linen wound in several layers on a large spool, the successive layers being properly separated by a flexible wire mat. This construction is shown in Fig. 1. The water entering the filter chamber at the top, flows down through the perforated core of the spool and filters out in all directions through the successive layers of Terry linen into the

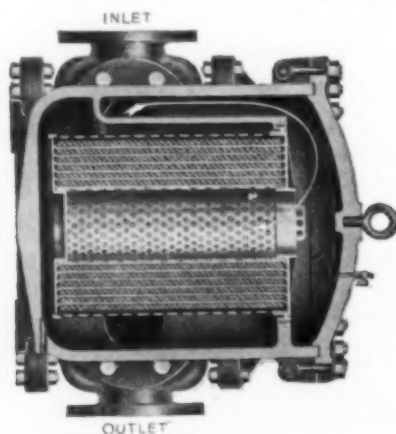


FIG. 1—FILTER AND GREASE EXTRACTOR

spacious spool chamber and the outlet. The large diameter and length of the spool provides large effective filtering area and maximum capacity of each layer with minimum resistance to the flow.

The Lagonda filter is a double unit machine consisting of two complete filters, each of which will furnish the rated capacity. The two filters are connected by double-control valves into a self-contained unit and the normal operating condition is to have one chamber in service at a time, leaving the other ready to be cut in for use when it becomes necessary to change the spool. There is, therefore, no interruption in the supply of filtered water, and in time of excessive demand, both filters can be cut in, in parallel, to double the capacity of the machine.

Under ordinary conditions the filter cloth need not be removed and cleaned oftener than every ten or fifteen days. The necessity for cleaning is indicated by the difference in pressure on the inlet and outlet side of the filtering material as indicated by the gages. This pressure difference increases as the filtering material

becomes clogged, and cleaning is advised when a difference of 10 or 12 lb. is reached.

To facilitate ease in cleaning, the covers of the filtering chambers are provided with hinged slot bolts and each chamber with a double-arm lifting davit mounted on ball bearings. When the cover bolts are loosened, the cover is easily raised and swung aside by the lower davit arm. The filtering spool is then lifted out by the self-locking block tackle suspended from the upper

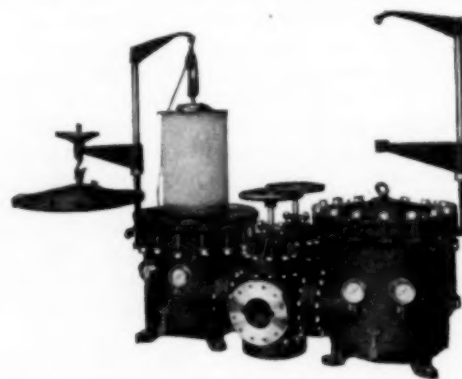


FIG. 2—GENERAL VIEW OF FILTER, SHOWING RAISING OF SPOOL

davit, as shown in Fig. 2. In this position the spool is allowed to drain for some time to prevent mussiness about the machines. As each machine is furnished with a complete extra spool, this can be inserted immediately and the fouled spool placed aside for cleaning.

To further increase the ease of cleaning and handling, a specially designed winder is furnished for unwinding and winding of the filtering cloth and spacing mat on the spool. The strip of Terry linen is washed like any piece of towelling and can be used repeatedly.

This new filter combines in a single, comparatively small unit, all the characteristics for oil extraction and filtration of the larger-space-taking filter beds. Placed between boilers and pumps, it offers one of the most simple, effective and economical means of filtering the boiler feed.

The Irite

The Gibb Instrument Company, Highland Building, Pittsburgh, Pa., has placed on the market a new instrument known as the "I-Rite," which is a very interesting combination of the principles of modern scientific pyrometry with what was sound in the old practiced furnaceman's use of his trained eye for estimating temperatures. Its principal claim for distinction is that it does not measure the furnace temperature, but measures directly the temperature of the piece under treatment. It is further distinctive in its simplicity and handiness, being of pocket size. The Gibb Instrument Company, in its new device, claims to have placed within the reach of the workman an apparatus that is simple, accurate and inexpensive.

The heat treatment of steel has ever been and, to a less extent, still is a matter of guesswork. The manufacturers of pyrometers have gone far in removing this factor. Thermoelectric pyrometers and resistance pyrometers properly installed and frequently checked give accurate measurements of the temperature at the point where they are installed.

Amazingly good results have often been obtained by the old-time furnaceman who treated steel by color, because he judged the temperature of the piece, not the furnace. A few of these men are still treating steel, and although their furnaces may be equipped with pyro-

meters, the treatment is still often done entirely by the eye. It has been claimed that while pyrometers are in general use as auxiliaries, eighty-five per cent of the actual heat treating is still done by the eye. The lack of uniformity in the product by this method is due solely to the lack of a permanent comparative color. The old-time furnaceman obtained best results only when he could carry this comparative color in his mind, and even to-day it is said that he frequently obtains better results than with the scientific method of pyrometers because by intuition he duplicates by the eye the temperature of a previously treated object.

The great obstacle against obtaining uniformity of product has been the lack of uniformity of temperature in different parts of the furnace. An instance is related of a sheet-annealing furnace which had a temperature of 900 deg. Fahr. in one part and 1800 deg. Fahr. in another. Twelve readings were taken at as many different points with as many different results. Again, an automobile part manufacturer had a number of furnaces 3 ft. x 2 ft. x 6 ft., the work from which did not run uniform. One furnace was equipped with recording pyrometers at six different points, the temperature of which fluctuated at times to the extent of 50 deg. Fahr. To best illustrate the absolute impossibility of obtaining uniformity, the electric furnace, with its uniform heat supply, cannot supply perfect distribution of heat, no matter how small the furnace. This has been recognized by the steel manufacturer to the end that he understands clearly that what he must know is not some temperature in the furnace, but directly the temperature of the material under treatment.

The new pyrometer claims to exactly duplicate the color of heated bodies and at the same time indicate the temperature on an accurately calibrated scale. It is possible for the user to read the temperature of the *piece* under treatment within 1 per cent to 2 per cent, re-



FIG. 1—IRITE

gardless of the furnace temperature. It is no longer necessary to take into account the length of time the body has been subjected to the specified temperature in order that it may assume this temperature. The pyrometer immediately shows either that the *piece* is or is not up to temperature and, in the latter event, how many degrees it must absorb to come up to the prescribed temperature.

Relative to the sensitiveness of the human eye and its ability to distinguish shades of color, an interesting experiment was carried on by Prof. E. L. Nichols of Cornell University. He placed ninety-two different shades of blue before fifty-four observers. The general average for placing these shades in proper relation was over 95 per cent. The extent of this sensitiveness is further attested in that in the practice of medicine the amount of hemoglobin in the blood is best determined by the "Hemoglobinometer," an instrument consisting of a graduated color with a calibrated scale to which is compared a drop of blood. An interesting fact in connection with this sensitiveness is that a man who is color blind can read with the same facility as one who is able to distinguish color, for the reason that while the color may not appear as red or orange he is still able to duplicate the intensity even though it appear green or blue.

The operation of the "I-Rite" is so simple that it can be advantageously be placed in the hands of the unskilled workman as the metallurgist. The construction is such that it cannot get out of order. While it is designed for the more precise temperature measurements of high-grade steels under treatment, inasmuch as it is made in two ranges, 1000-1800 deg. Fahr. and 1800-2300 deg. Fahr., it can also be used for taking the temperature of heated bodies either within or without a furnace. This makes it possible to obtain temperatures of heated steel as an ingot, billet, rail, armor plate, structural shapes, forging, casting, etc.

Industrial Developments in Chattanooga

Much industrial news showing development in Chattanooga, Tenn., has emanated from that city in recent months—even during the business depression—but the most important announcement made for some time is the formation of the Chattanooga Steel Company, a \$2,000,000 corporation, charter for which was filed March 7. Even prior to that date several important contracts had been let, as the promoters are anxious to have the plant in operation Sept. 1.

The charter members of the corporation are C. E. James, Webster T. James, Herbert Bushnell, vice-president Citizens' National Bank; T. R. Preston, president Hamilton National Bank; W. A. Sadd, president Chattanooga Savings Bank; C. C. Nottingham, vice-president First National Bank; Z. C. Patten, Jr., president St. Elmo Bank & Trust Company, and identified with several industries.

There will be two 75-ton open-hearth furnaces producing a maximum of 336 tons per day. The blooming mill capacity will be 1000 tons. The output will be marketed for the present in a semi-finished state, but at the proper time the company will put into a finished state all its output.

The mill will be built and equipped under the supervision of the W. R. Miller Company, Pittsburgh. This concern, too, will furnish the furnaces. Contract for the blooming mill was let to the National Roll & Foundry Company, Pittsburgh, and the Westinghouse Electric Company will furnish the electric motors, which will aggregate about 6000 hp. These two contracts, it is reported, represent \$300,000.



FIG. 2—USE OF IRITE AT FURNACE

The plant will be located north of the Tennessee River from Chattanooga on a 100-acre tract, which will provide ample space for the initial buildings and future contemplated expansion. Railroad connection will be provided by an extension to the site from the spur track now being built by Mr. James from the new factory district known as "Moccasin Bend" to the trunk lines at Hixon, Tenn. As the property lies along the Tennessee River, there will be facilities for receiving water shipments of raw material, and also for shipping finished products in boats to Western and Southwestern markets. The recent decision of the Interstate Commerce Commission, recognizing the Tennessee River and encouraging the improvement of river freight service to its present good condition, was a factor in bringing the steel mill negotiations to a head, and the mill will be an important patron of the belt line now operating on regular schedule from Chattanooga to Ohio River points, for ultimate destinations such as St. Louis, Chicago, etc. The location selected will give the company nearly $\frac{1}{2}$ mile of river front, besides physical connection with the trunk lines entering Chattanooga. With this river location they can count on coal by river at a rate of 10 to 12 cents per ton as against a minimum of 40 cents by rail. On finished products they can count on a rate to Ohio River points of not to exceed \$1.50 a ton on bloom or billets. This will place their product in St. Louis on a water rate of not to exceed \$2.25 a ton and for Chicago delivery net in excess of \$2.60 per ton.

The initial plant, in all departments, will employ about 600 men, a good portion of whom will be expert rollers imported from other places. When the program is put in effect fully the employees will number from 1800 to 2000. Land around the mill site is well adapted to an industrial community, and it is anticipated that many homes for workmen will spring up there.

The buildings will be of concrete and steel. The Converse Bridge & Steel Company, Chattanooga, probably will fabricate and erect the steel frame. Construction will be facilitated by the fact that Mr. James has the structural steel, having bought it some time ago. The plant will represent the last word in construction. Electric power will be used throughout, bought from the Chattanooga & Tennessee River Power Company, operating the Hale's Bar hydroelectric development built by the late Anthony N. Brady and associates, including Mr. James.

It is stated that the completed plant (that is, when the finishing department is added) will be some 2800 ft. long and 200 ft. wide.

Chattanooga and immediate vicinity will provide sufficient pig iron, scrap iron and steel to feed the steel mill. The Chattanooga Iron & Coal Corporation is now making at least 200 tons of pig iron daily, much of which moves by river to Ohio River points for Chicago and St. Louis. The mill will use about 65 per cent scrap and 35 per cent pig.

There is a strong feeling, borne out by precedent and the logic of the situation, that the steel mill will be followed by other important allied industries. Among the first of co-ordinate character, it is pointed out that another by-product coke-oven plant and a tar-treating plant suggest themselves. While the steel mill overtops everything else under way or definitely projected, it is one of many things contributing to the present prosperity and certainty of future rapid developments of Chattanooga. Among the other items may be mentioned a \$200,000 plant of the Marion Extract Works, under way, and a \$200,000 chemical plant being built by the Chattanooga Gas Coal Products Company to develop some of their by-products.

Ferrosilicon Plant On the Mississippi

An electric furnace plant for the production of 50 per cent ferrosilicon is expected to be in operation early this spring at Keokuk, Iowa. The operating company is the Keokuk Electro Metals Co., Keokuk, Iowa. The contemplated production is 2000 to 3000 tons per year of 50 per cent ferrosilicon, and the location is favorable to the Middle Western steel plants.

The officers of the new company are: G. E. Weisenburger, president; M. H. Christopherson, vice-president, and John Dillon, secretary and treasurer. W. D. Baldwin and C. G. Comstock, president and vice-president of the Otis Elevator Co., are among the directors.

The Goldschmidt Thermit Co., 90 West Street, New York (W. C. Cuntz, general manager), are the sales agents for the new company.

Industrial Notes

Ferromanganese.—E. J. Lavino & Co., Bullitt Building, Philadelphia, Pa., have purchased the Sheridan furnace of the Berkshire Iron Works, Sheridan, Pa., and will repair it and start the manufacture of 80 per cent ferromanganese from Brazilian ore. The stack has been idle for two or three years.

New Japanese Aluminium Plant.—It is reported that a new Japanese aluminium plant is to be established at Kachigawa, near Nagoya, with a capital of \$498,000. Clay deposits near by will be used. The price of aluminium has advanced to such an extent that two of the three manufacturers of aluminium articles have had to shut down.

The Citizens Gas Company of Indianapolis expects to install in about thirty to sixty days a plant for the manufacture of sodium cyanide. The company is now extracting benzol and toluol.

Tin Smelting Begun at Perth Amboy.—Operations were commenced at the new tin smelting plant of the American Smelting & Refining Company at Perth Amboy, N. J., during the first week in March. The reverberatory smelting plant and electrolytic refinery will treat at present about 750 tons of 60 per cent tin concentrates per month. The capacity of the plant is 1200 tons per month.

Potash from Cement Plants.—The Security Cement & Lime Company, with plants at Security, Md., and at Berkeley Station, are considering the installation of an electrical precipitation system as adopted in California. Vice-President and General Manager J. J. Porter recently made a trip to California to inspect the recovery of dust there by a Portland cement company. The rock used at the Security plant is stated to be rich in potash.

Shortage of Paper Material.—The Secretary of Commerce is sending to about 4000 commercial organizations a letter inviting their co-operation in efforts to relieve the present serious shortage of paper material, according to Commerce Reports. The president of a large paper manufacturing company urges the Department of Commerce to make it known that the collecting and saving of rags and old papers would greatly better existing conditions for American manufacturers. A large part of the enormous amount of paper and paper board manufactured is burned or otherwise wasted after use. This has to be replaced by new material.

Pocket Carbon Dioxide Indicator.—The Bacharach Industrial Instrument Company, Pittsburgh, Pa., supply a pocket CO₂ indicator which has found considerable use in the Pittsburgh district, but which, perhaps,

is not so well known in other places. The indicator is conveniently arranged in a small case, and can be operated by an inexperienced man. A test takes about 2½ minutes and the operation is extremely simple.

Investigation of Phosphate in Alberta.—An investigation of a reported discovery of phosphate in Alberta has been made by the Canadian Department of Mines and the results published in Bulletin No. 12, recently issued. The author is Hugh S. de Schmid. Deposits were found in the Banff district, which are, however, unsuited to the manufacture of superphosphate by the sulphuric acid method, owing to the low content of tricalcic phosphate (43.7 per cent average), and to the large amount of silica present, 43.3 per cent average). Possibly the deposits might prove suitable for treatment by one of the thermic processes (such as electric furnace treatment) that have lately been proposed.

Mineral Production of Canada in 1915.—A preliminary report has been issued by the Department of Mines. Bull. 408. The report was prepared by John McLeish, chief of the Division of Mineral Resources and Statistics.

Testing of Hydrometers.—The Bureau of Standards has recently issued a circular (No. 16) describing the testing and securing of standards for hydrometers. Hydrometers are classified, manipulation is described and tests performed by the Bureau are included. The information is valuable and should prove very interesting.

The International Oxygen Company has issued a new catalog, No. 3, describing its Bipolar oxygen and hydrogen generator.

The Asbestos Protected Metal Company of Pittsburgh announces the opening of a new office in the Praetorian Building, Dallas, Tex., with Mr. T. R. Galey as manager thereof, and a new office in the Hurt Building, Atlanta, Ga., with Mr. J. R. Nichols as manager thereof.

The New Jersey Zinc Company, 55 Wall Street, New York, have announced the following changes in their organization, effective March 1, 1916: Mr. E. V. Peters, assistant general sales manager; Mr. A. H. Peck, sales manager; Mr. H. Hardenbergh, general purchasing agent; Mr. W. J. Lee, Jr., purchasing agent.

The United States Cast-Iron Pipe & Foundry Company announces the removal of its Southern sales and traffic offices from Chattanooga, Tenn., to 1002 American Trust and Savings Bank Building, Birmingham, Ala. This change becomes effective April 1, 1916.

The Kansas City Testing Laboratory, Kansas City, Mo., has issued an interesting pamphlet descriptive of petroleum and its uses. The pamphlet contains much valuable information condensed into a small space, and includes analyses of the natural content of typical crude oils, an outline of typical refinery practice and various specifications and tables.

New Chemical Laboratory for Detroit.—A fully equipped commercial laboratory has been opened at 445 Howard Street, Detroit, by the Wolverine Laboratories Company. L. F. Miller, formerly chief chemist of the Timken-Detroit Axle Company, will be in direct charge. The company will specialize in analyses of iron, steel, coal, oils and non-ferrous alloys.

The firm of **L. O. Koven & Brother**, Jersey City, N. J., will in a short time remove its main office from 50 Cliff Street, New York, to 154 Ogden Avenue, Jersey City, N. J. This change has been in contemplation for some time. The new office building, which has been recently reconstructed, has four floors and is well equipped.

Personal

Mr. C. G. Atwater of the Barrett Company, New York, presented an illustrated lecture on "the utilization of by-products from the manufacture of coke" at a meeting of the Engineers' Society of Western Pennsylvania, held in Pittsburgh, March 28, 1916.

Mr. A. L. Blomfield, for many years in the employ of Bewick-Moring & Co., as metallurgist, and for the last eight years mill superintendent of the Golden Cycle mill at Colorado Springs, has become associated with The Dorr Company, successors to The Dorr Cyanide Machinery Company. Mr. Blomfield has taken charge of the metallurgical consulting work for the company, with headquarters at Denver. He retains connection with the Golden Cycle mill as general superintendent.

Mr. W. Walley Davis of Harrisburg, Pa., superintendent of the Pennsylvania district plants of the Semet-Solvay Company, has been appointed superintendent of the Chicago district plants and manager of the By-Products Coke Corporation with headquarters in Chicago. Mr. Davis, who has been in charge of the plants at Steelton, Lebanon and Dunbar, Pa., since 1907, came to Harrisburg from Milwaukee, where he was in charge of coke plants.

Mr. Harry L. Day has tendered his resignation as general manager for the Federal Mining & Smelting Company, one of the largest operating companies in the Coeur d'Alene district, Idaho. He will be succeeded by Mr. F. H. Brownell of Seattle, Wash., formerly president of the company and now chairman of the board.

Mr. Herbert H. Dow, general manager of the Dow Chemical Co., Midland, Mich., was tendered an agreeable surprise on his fiftieth birthday, Saturday, Feb. 25. Several employees of the company, mostly heads of departments, arranged a surprise banquet for him at the Wenonah Hotel in Bay City, Mich.

Mr. C. A. Grasselli, who has served a long time as president of the Grasselli Chemical Company, has retired from that position to become chairman of the newly created board of directors. Mr. Grasselli's son, T. E. Grasselli, succeeds him as president of the company.

Mr. Glenn N. Hastings of Chicago has been appointed Middle West representative of Hamilton & Hansel, New York, agents for the Rennerfelt electric furnace.

Dr. Carl Hering, consulting engineer of Philadelphia, Pa., has removed his office to 210 South 13th Street, where more elaborate laboratory facilities are at his disposal.

Mr. Robert M. Keeney has joined the forces of the Snyder Electric Furnace Company of Chicago, where he will have charge of the development work. Mr. Keeney has had a broad experience in electric furnace research, covering the production of iron, steel and ferroalloys in the electric furnace, and the electric smelting of lead, copper and zinc ores. His work has been especially directed toward the production of ferroalloys and electric smelting. In this connection he visited many electric furnace plants in Sweden, England, France and Germany. Before his connection with the Snyder Electric Furnace Company, Mr. Keeney was electrometallurgist of the U. S. Bureau of Mines, at Pittsburgh and Salt Lake City, mill superintendent of the Baker Mines Company, Cornucopia, Ore., and metallurgist of the Standard Chemical Company, Canonsburgh, Pa. In the latter connection Mr. Keeney was engaged in the production of ferro-

vanadium and developed a process for the manufacture of ferrouanium. While in the Western States, Mr. Keeney made an extended study of the application of the electric furnace to the smelting of ores, flotation concentrate, and cyanide precipitate.

Mr. W. A. Neill, for many years engineer of the mining department of Allis-Chalmers Company, has moved to Denver and became associated with The Dorr Company, successors to The Dorr Cyanide Machinery Company as mechanical engineer.

Mr. E. L. Newhouse, Jr., is general manager for the newly organized Garfield Chemical and Manufacturing Company, which will produce sulphuric acid in the vicinity of Salt Lake City, Utah.

Mr. Nathan Owitz has been appointed sales manager of the J. P. Devine Company of Buffalo, N. Y., manufacturers of vacuum drying apparatus and chemical equipment, and will be located at the main office and works at Buffalo. Mr. Owitz was formerly with the Wheeler Condenser & Engineering Company of Carteret, N. J.

The marriage is announced of Dr. Carl G. Schluederberg of the Westinghouse Electric & Mfg. Co., Pittsburgh, on Feb. 25, 1916, to Miss Roberta Skene.

Mr. M. Yamashita, mining engineer for Mitsubishi & Co. of Japan, is visiting ore-dressing plants in Colorado, New Mexico and Arizona on his return to Japan. He expects to sail from San Francisco on March 25.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath Cathodes

(Continued)

583,255, May 25, 1897, Ernest Auguste Georges, called Charles Street, of Paris, France, assignor to the Electro-Metallurgical Company, Limited, of London, England.

Relates to cathodes for electrodeposition; the cathode is preferably a thin sheet of flexible metal capable of being rolled upon itself. The cathode is preferably rolled into a cylinder, and the deposit produced upon the outer surface. Upon rolling the cathode into a cylinder of smaller diameter, the deposit peels off.

591,571, Oct. 12, 1897, Joseph W. Richards and Charles W. Roepper of Bethlehem, Pa.

Relates to the electrolytic recovery of metals from their solutions, and employs a highly porous cathode, such as shavings, masses of excelsior, matted or tangled threads, etc., which have been made conducting by coating with graphite, or by soaking in a solution from which metal can be precipitated either by reduction, such as a silvering solution, or by precipitation, such as gold from gold chlorid and ferrous sulfate, etc. The cathode may also consist of such substances as interlaced wood fiber, corn-pith, masses of linen, paper, hemp, jute or cocoa fiber matted or woven, fine flaky or granular masses such as wood-sawdust, etc., which have been made conducting. The mass of loose material is held in a coarse bag, such as netting, and during deposition, the metal deposits throughout the mass on all the coated surfaces. After the deposition, the deposit is washed and dried, and may then be ignited.

The residue is collected in any suitable way, or may be melted down in a crucible under a flux, such as borax, etc.

602,212, April 12, 1898, Emile Louis Dessolle, of Epinay sur Seine, France.

Relates to making electrodeposited sheets or hollow forms, such as reflector shades, etc., which may or may not be gold or silver plated. The cathode surface is coated electrolytically with either platinum, or nickel, or gold, or other metal capable of sufficiently occluding hydrogen. The coated cathode is then connected as a cathode and immersed in an acid or alkaline electrolyte, using an insoluble anode. The cathode is agitated to mechanically dislodge bubbles of free hydrogen, this electrolysis being carried out at from two and one-half to three volts. After sufficient hydrogen has been occluded, the cathode is removed and polished. It is then immersed in the solution from which the sheet or hollow form is to be made, and deposition of the metal effected, the cathode being continually agitated during deposition. After it is finished, the deposit may be readily stripped from the occluded hydrogen surface. For an article made of copper, the cathode surface should be platinum, while for silver, a cathode surface of nickel or gold is preferred.

630,796, Aug. 8, 1899, Hermann Becker of Paris, France.

Relates to preparing cathodes for the easy removal of deposits. The cathode is preferably highly polished silver, or silver-plated metal, which is rubbed with flowers of sulfur, or precipitated sulfur, or a sulfid coating may be produced thereon by any other suitable method. The sulfid coating may be polished after it is produced if desired. In the treatment of cyanid solutions for the recovery of gold, silver, etc., the cathodes may be of sheets of iron, copper, lead, nickel, or of iron tinned, coppered, nickeled, or the like, the surfaces being sulfureted and polished as described above. The deposit acquires the polish of the cathode, and is readily removed therefrom. With very thin deposits of gold, the gold may have a reinforcing deposit of copper to facilitate its removal.

Book Reviews

The Metallography and Heat Treatment of Iron and Steel. By Albert Sauveur. Royal octavo (17 by 27 cm.), 486 pages, 438 illustrations; price \$6.00. Boston: Sauveur & Boylston.

This is a revised second edition of Professor Sauveur's well-known book on metallography of iron and steel. It is clearly written, very practical, beautifully illustrated, prettily printed. The new edition has had almost every chapter revised, over fifty pages of new matter and 100 illustrations added, and the book entirely reset. We commend the postponement of the phase rule and equilibrium diagram to the closing chapters, when the student has acquired familiarity with the metallographic facts which these principles co-ordinate.

It is a well-written and extremely useful book, and the new edition is superior to the former.

The "Mechanical World" Electrical Pocket Book for 1916. 298 pages. 130 illustrations. Price, 25 cents. Manchester: Emmott & Company, Ltd., Baltimore. The Norman, Remington Co.

A large variety of subjects are taken up in this little book and the space devoted to each is consequently not large. The information is given in very concise form and a great many of the subjects are just touched upon. Among the new features of the present issue is a section on switch gears and switch boards. A new section is given on earthing while the whole book has been generally revised. The book contains sufficient tables for ordinary work, is clearly written and should be useful.